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Scenario Generator Configuration Guide

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1 Introduction

This guide describes the content of the Scenario Generator tree structure, including the available containers, models, submodels, input parameters, output variables, and analysis options for the various models. The layout of this guide mimics the Scenario Generator tree structure. Each model is described in a general way and its inputs, outputs, and analysis options are given.

For some model types, you can choose the calculation method. The inputs, outputs, and analysis available for each of the different types are listed separately in this guide. When different models are available, the model type is given in brackets. *For example,* NominalYieldCurve [AnnualLMM] gives details of the AnnualLMM type of the NominalYieldCurve.

Where a model availability is stated, it means that the model is available only for the specified trees. If no availability is stated, the model is available for all trees.

Note Your license to the Scenario Generator product and chosen use of the product may not include all the features and functionalities described in this guide. Certain features and functionalities are only available if optional modules or features are licensed for an additional fee.

1.1 Related Documentation

The complete documentation set for this software includes:

- *Scenario Generator Readme Documentation Quick Start*
- *Scenario Generator Release Notes*
- *Scenario Generator What's New*
- *Scenario Generator User Guide*
- *Scenario Generator Configuration Guide*
- *Scenario Generator Methodology Guide*
- *Scenario Generator HPC Setup and Configuration Guide*
- *Scenario Generator Digipede Setup and Configuration Guide*
- *Scenario Generator Installation Guide*
- *Scenario Generator Developer Guide*
- *Scenario Generator Managed Portfolios Getting Started Guide*
- *Scenario Generator Managed Portfolios Methodology Guide*
- *Scenario Generator Getting Started Guide for Market Consistent Simulations*

2 Top-Level Nodes

The top-level node in the Scenario Generator is the Simulation node, and under this node, the node for the type of model tree. Your license type determines the tree or trees to which you have access.

Node	Model tree
ESG	Economic Scenario Generator
RSG	Risk Scenario Generator

2.1 Simulation

The following table describes the parameters that are globally applicable to all models in the simulation.

Submodels

Name	Description
ESG	The simulation root for the Economic Scenario Generator.
RSG	The simulation root for the Risk Scenario Generator.

Input variables

Name	Description	Availability	Conditions
Comments	The comments parameter has a special icon: . This icon shows that this parameter is for information only and does not affect the simulation. Use it to store comments or notes about the simulation file.		
NumberOfTrials	The number of trials to run. How many trials you set depends on your precision requirements. The more trials, the more precise the results are likely to be.		
InitialTrialNumber	This parameter is used as a label in the output file and does not affect the simulation itself.	ESG	
Timesteps	The number and length of time steps and the simulation horizon these time steps give (the total time the simulation covers). You can select daily, weekly, monthly, quarterly, semi-annual, and annual time steps. The simulation runs from the smallest unit up to the		

Name	Description	Availability	Conditions
	largest. *For example*, a simulation can be set up to run 24 monthly time steps, followed by 12 quarterly, 6 semi-annual and 6 annual steps. The simulation horizon is then 14 years.		
RandomNumberGenerator	Select the pseudorandom number generator that you want to use for your simulation: **WichmannHill** or **MersenneTwister**. For more information about how the software generates pseudorandom numbers, see the Pseudorandom Number Generation methodology.		
MomentMatching	To apply moment matching adjustment to the shocks, select one of the following values: • **None**—No moment matching adjustment • **Mean** • **MeanAndVariance** • **MeanVarianceAndAutoCorrelations** For **MeanVarianceAndAutoCorrelations**, **NumberOfTrials** must be greater than $\min(\text{number of timesteps}, \text{MomentMatchingBatchSize})$ For more information about moment matching, see the Moment Matching methodology.		
MomentMatchingBatchSize	The number of simulation time steps used in the autocorrelation correction when using the moment matching **MeanVarianceAndAutoCorrelations** feature. To use batching, select a value from 1 to the number of time steps. Batching enables you to reduce the simulation run time at the expense of allowing some residual correlations to remain. For more information about batching, see the Scenario Generator Methodology Guide. To disable batching, set **MomentMatchingBatchSize** to **0**.		Enabled only if **MomentMatching** is **MeanVarianceAndAutoCorrelations**.
UseAntithetics	Specifies whether to use antithetic variables (**True**) or not (**False**). If **True**, the simulation has to run an even number of trials. Antithetic random variables are perfectly negatively correlated and an effective way to reduce variance.		
RandomNumberSeed	A number that the random variable generator uses as a starting point when creating a series of numbers. If you set **SeedByTrial** to **True**, this seed must be an integer between 0 and 30000.		
SeedByTrial	Controls the seeding methodology. Possible values: • **True**—Reseed each trial. • **False**—Use one seed for the entire simulation.		
UseRiskNeutralValuation	Set to **True** for market-consistent simulations, or **False** for real-world simulations.	ESG	
RebalancingStrategy	Rebalancing strategy for the numeraire bond. Currently the only available strategy is to rebalance on maturity. This parameter is only used when the base economy is	ESG	

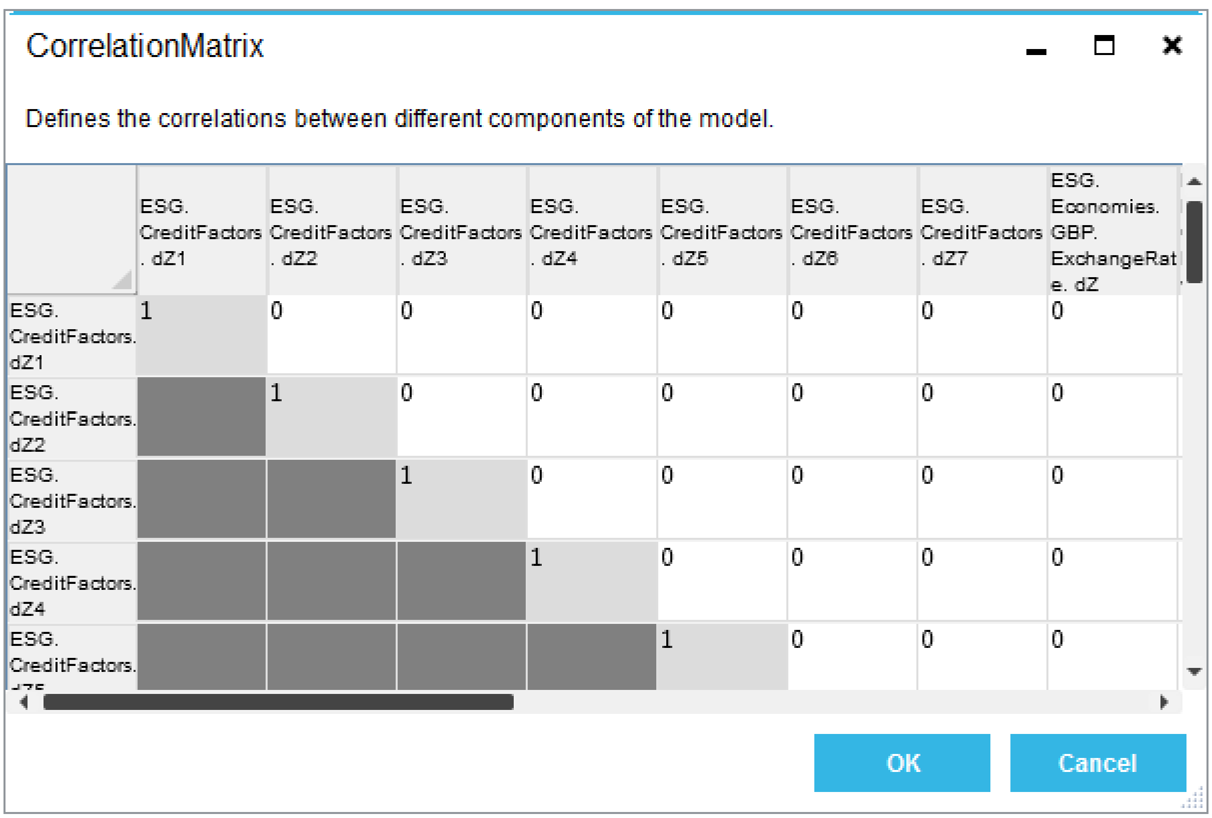
Name	Description	Availability	Conditions
	using a LIBOR market model (LMM) nominal yield curve.		
MaturityOfNumeraireBond	Maturity term of the numeraire bond in time steps. This parameter is only used when the base economy is using a LIBOR market model (LMM) nominal yield curve.	ESG	
BaseEconomy	The base economy must be specified for all simulations, and is used to calculate exchange rates, quanto FX adjustments, and so forth.		
BaseDate	Specifies the simulation's start date. This parameter is only used when specific bond portfolios are modeled and then it defines the date that all bond maturities are referenced against.		
EnsureValidBondTerm	If you want to adjust the Term, TermDeclineRate, and Frequency parameters of generic bond portfolios so that income payments are more likely to coincide with time steps, select **True**. For more information about the adjustment, see GenericBondPortfolios.	ESG	
CorrelationMatrix	Defines the correlations between the underlying shocks used in the models using a matrix approach. For more information about the correlation matrix, see Correlation Matrix Format.		
DependenceStructure	Specifies the dependence structure to be used for the simulation, with a choice of Gaussian copula, T copula, and individuated t copula. The preset copula is the Gaussian copula, which was also the underlying copula in all previous versions of the ESG. For more information about the differences in dependence structure and the available choices, see the Dependence Structure and Copulas methodology .		
TCopulaDegreesOfFreedom	The number of degrees of freedom of the t copula.		Enabled only if **DependenceStructure** is **TCopula**.
IndividuatedTCopula DegreesOfFreedom	The degrees of freedom parameter set for the individuated t copula. There is a number of degrees of freedom parameter for each risk factor (shock) that is a part of the correlation matrix. To set the degrees of freedom for a shock to infinity, to simulate a Gaussian copula, enter **-1** in **DegreesOfFreedom** for that shock.		Enabled only if **DependenceStructure** is **IndividuatedTCopula**.
EquityAssetCorrelationMethod	Specifies how the correlation of equity assets is done, either via the correlation matrix or described via the equity asset factor model.		
CorrelateEquityJumpShocks	To correlate jump shocks in equity assets, select **True**. To use this feature, you must have more than one parent or child equity asset correlation model, with SVJD as their Sigma submodel, and ArrivalRate of the Jump submodel must be strictly positive. Equity assets that do not meet this specification do not use this feature. For more information about these asset types, see ParentEquityAssetCorrelationModel and ChildEquityAssetCorrelationModel. For more		Enabled only if **EquityAssetCorrelationMethod** is **CorrelationMatrix**.

Name	Description	Availability	Conditions
	information about this feature, see the Correlation of Equity Assets methodology.		
CreditMigrationFactorMethod	Specifies the credit migration factor method to use and the calculation of the StandardisedShock output of equity assets: • **EquityZScore**—The application uses the legacy StandardisedShock method with DecorrelatedZScore as the credit migration factor. • **StandardisedExcessLogReturn**—The application uses the sum of the decorrelated StandardisedExcessLogReturn StandardisedShock and ParentEquityAsset.ZScoreMPR as the credit migration factor. • **UnitVarianceSharpeRatio**—The application uses the excess log return without Itô terms and scaled to unit variance of the equity selected in FixedIncome.***.EquityAsset or in the ConditionalTransitionProbability output of G2 credit models.		**UnitVarianceSharpeRatio** can only be used if **UseRiskNeutralValuation** is set to **False**.
StochasticRunType	Determines how the application calculates model volatility in the simulation. Possible values: • **Stochastic**—The application runs the simulation with the model parameters that you set in the user interface. • **Deterministic**—The software adjusts the parameters that you set in the user interface to run the simulation with zero volatility. The software does not reflect these changes in the user interface. For more information about the adjustments for each model, and the supported models for deterministic, see the Deterministic Scenario methodology. **Note** Deterministic is supported only for risk-neutral simulations.		
CreditFactorSubdivisions PerYear	The number of subdivisions per year for factor-based credit model shocks.		
MacroFactorSubdivisions PerYear	The number of subdivisions per year for macroeconomic factors.	ESG	
CreditClasses	Specifies the credit classes to use in compatible credit models. Credit classes must be defined in a strictly decreasing rating order with the most credit-worthy rating at the top of the list. Govt and Default classes should be excluded from this list. Entries must be unique, alpha-numeric, case sensitive, and not contain any special characters (with the exception of + and -). Predefined entries (from top of list): AAA, AA, A, BBB, BB, B, CCC.		
UserDefinedOutputMappings	Contains any mapping names that you define for output parameters, for Trial/Timestep, Trial/Parameter, MetaRisk, and MG-ALFA files. For more information about editing output names, see the Editing an Output Name user guide section.		Enabled only if **EnableUserDefinedOutputMappings** is **True**.

Name	Description	Availability	Conditions
EnableUserDefined OutputMappings	Defines whether any output mapping names that you define are visible on the Output screen and used in the output files.		
ErrorOnUnknown UserDefinedOutputMappings	Defines whether an error is shown if you map a new name to an output parameter that does not exist. Possible values: • **True**—If the application is unable to map a name when you run a simulation, the application stops the simulation and displays an error message. • **False**—If the application is unable to map a name when you run a simulation, the application continues and ignores the unmapped name.		Enabled only if **EnableUserDefinedOutputMappings** is **True**.
PFaroeScenario	Specify the ScenarioType and Reference name for the scenario set to include in PFaroe output files. Specify whether a TrialCap should apply in the output file for time steps over one year.		

2.1.1 Correlation Matrix Format

This matrix reflects all shocks in the simulation that are able to be correlated. This matrix can contain a row (and column) for each of the shocks to economic models (nominal and real yield curves, inflation, exchange rate, credit) as well as any shocks required for assets (equity assets and fixed income assets) and risk drivers. The size of the correlation matrix is always kept up to date, meaning that if a new model, economy, or risk driver is added (or removed) the correlation matrix is augmented (or reduced) correspondingly.



The entries in the correlation matrix form part of the calibration. Do not edit the values unless you fully understand the potential impacts of changing the calibration in this way. There are various constraints on the structure of this matrix: it must be symmetric with all entries in the leading diagonal equal to one and it must not have any negative eigenvalues.

2.2 ESG and RSG

The simulation is arranged in the form of a tree. Going down a particular branch of the tree implies descending from a global view to a more specific view. *For example*, a simulation might contain several economies. Individual economies contains models that describe the dynamics of particular quantities. Parameters, which are defined at a particular branch of the simulation tree apply to the whole branch. *For example*, the number of simulation time steps, and the risk neutral simulation are defined at the simulation root.

Several models have different implementations available. For more information about the different implementations available for models, see the Scenario Generator Methodology Guide. This guide details the parameters and outputs associated with the family of models. The outputs and tests are similar across various allowable models. *For example*, the nominal yield curve. However, the input parameters can differ vastly depending on the actual model implementations.

Models in the simulation tree can have several input parameters, outputs, and analysis tests associated with them. Outputs can be selected and added to an output file. Input parameters are used to set up the simulation and govern how it is run. During the simulation run, several outputs are produced. The performance of the Scenario Generator software, to a certain extent, depends on the number of outputs you select for observation.

Containers

Name	Description
Economies (addable in RSG)	Contains models representing economies, *for example,* USD, GBP, and AUD
Assets (addable in RSG)	Contains groups of assets: Cash, equity, debt, and derivatives.
Portfolios (addable in RSG)	A container for modeling various types of portfolios.
ActiveManagementModels	Contains models for active management risk.
Processors (addable in RSG)	Enables you to create custom calculations on software outputs.

Addable containers

Name	Description
RiskDrivers	A container to hold risk drivers that are peripheral to the core structural models of the Scenario Generator simulation. Use these drivers to represent non-market or other risk factors.

Outputs

Name	Description	Availability
UserData [Value]	Any constant value. You can add any number of UserData outputs to an output file.	

Name	Description	Availability
Time [Units]	The elapsed time in years or months of each time step from step 0.	
Date	The date of the time step, as a string, where time step 0 is equal to the base date.	ESG

3 Economies

The economies container contains the collection of economies that you want to model. The economies node itself does not have input parameters or output variables, it is a container for the economies in the model. You must add at least one economy under the economies node, for use as the base economy.

Addable submodels

Name	Description
Economy	Name the economy according to its official International Organization for Standardization (ISO) currency code, to match the convention in calibration files, *for example,* **GBP** for the UK, or **USD** for the US economy. The number of economies that can be added depends on the terms of the license you are using.

3.1 Economy

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An individual economy with models for interest rates, inflation, exchange rate, credit risk, and various indices.

Submodels

Name	Description	Availability
ExchangeRate	The model for exchange rate that links currency exchange between this economy and the base economy. You can use one of the following models: • ExchangeRate [ExchangeRate] • ExchangeRate [PurchasingPowerParity] • ExchangeRate [InterestRateParity]	
MacroEconomy	Enables modeling of macroeconomic variables. Possible models: • MacroEconomy [DummyMacroEconomy]—Preset model for if your license does not allow macroeconomic modeling. • MacroEconomy [MacroG1]	ESG

Containers

Name	Description
RealYieldCurves	Models one or more real yield curves for this economy.
NominalYieldCurves	Models one or more nominal yield curves for this economy.
InflationRates	Contains models for core inflation and any additional inflation rates (inflation wedges).
CreditModels	Contains models for credit rating transitions and municipal spreads.

Addable containers

Name	Description
RiskDrivers	After they are added, these containers can be filled with models representing any additional risk drivers associated with this economy that cannot be represented adequately using any of the existing models. *For example*, these risks could include non-market risks like GDP, NAE, policy lapse, operational risks, and so forth.

Input variables

Name	Description
InitialDeflatorValue	The base value for deflator outputs.

Outputs

Name	Description
Deflator	The deflator for this economy. $\text{Deflator}(t) = \text{InitialDeflatorValue} \times \frac{\text{BaseCashTRI}(0)}{\text{BaseCashTRI}(t)} \times \frac{X_0}{X_t}$ where: • $\text{BaseCashTRI}(t)$ is the cash total return index of the primary nominal yield curve of the base economy. • $X_t = \text{ExchangeRate.NominalValue}(t)$ is the nominal exchange rate at time *t*. For the base economy, $X_t = 1$ for all *t*.
DeflatorProphet	The deflator for this economy (Prophet specific). $\text{DeflatorProphet}(t) = \text{InitialDeflatorValue} \times \frac{1}{\text{BaseCashTRI}(t)} \times \frac{1}{X_t}$
InverseDeflator	The inverse of the deflator for this economy.
NominalZCBP [CreditClass, Maturity, Seniority]	Outputs the zero coupon bond price, for the specified credit class and maturity. This output is calculated in different ways depending on the interest rate model that you select.
NominalSpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $\text{NominalSpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority}, t) = \left(\frac{1}{\text{NominalZCBP}(\text{CreditClass},\text{Maturity},\text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$

Name	Description
RealZCBP [CreditClass, Maturity, Seniority]	The price of a zero coupon index-linked bond of the specified maturity. This output is calculated in the real yield curve model.
RealSpotRate [CreditClass, Maturity, Seniority]	Annually compounded real spot rate at the specified maturity. Calculated using the formula: $\text{RealSpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},t) = \left(\frac{1}{\text{RealZCBP}(\text{CreditClass},\text{Maturity},\text{Seniority},t)}\right)^{\frac{1}{\text{Maturity}}} - 1$
NominalForwardRate [CreditClass, Maturity, Seniority]	Equal to the ForwardRate output from the nominal yield curve model that you are using.
NominalAnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity and one payment per annum. Calculated using the formula: $\text{NominalAnnuityPrice}(\text{CreditClass},\text{Maturity},\text{Seniority},t) = \sum_{\tau=1}^{\text{Maturity}} \text{NominalZCBP}(\text{CreditClass},\tau,\text{Seniority},t)$

3.1.1 RealYieldCurves

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The Scenario Generator software supports multiple real yield curves for each economy. There is always one primary real yield curve in every economy, but there can be any number of added real yield curves, and all are housed in this container.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
RealYieldCurve	The core real yield curve for the economy. Can be one of the following models: • RealYieldCurve [TwoFactorVasicek] • RealYieldCurve [TwoFactorBK] • RealYieldCurve [TwoFactorBKExt] • RealYieldCurve [AnnualGLMM, SemiAnnualGLMM, MonthlyGLMM] • RealYieldCurve [TwoFactorHullWhite] • RealYieldCurve [DeterministicYieldCurve]

Addable submodels

Name	Description
RealYieldCurve	Additional real yield curve for the economy. Can be one of the following models: • RealYieldCurve [TwoFactorVasicek] • RealYieldCurve [TwoFactorBK] • RealYieldCurve [TwoFactorBKExt] • RealYieldCurve [AnnualGLMM, SemiAnnualGLMM, MonthlyGLMM] • RealYieldCurve [TwoFactorHullWhite] • RealYieldCurve [DeterministicYieldCurve]

RealYieldCurve [TwoFactorVasicek]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The two-factor Vasicek model allows negative real interest rates. It has an imperfect correlation between different points on the yield curve, is mean-reverting and relatively simple and tractable.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	The short rate is modeled using a one-factor Vasicek model.
MeanReversionLevel	The mean reversion level is modeled using a one-factor Vasicek model.
TermPremium	The market price of risk for the interest rate model. Can be either TermPremium [ConstantTermPremium] or TermPremium [DualTermPremium].

Input variables

Name	Description
InitialIndexValue	The base value for index outputs.
DeterministicRecalibrationMaximumMaturity	The highest maturity of bond yield used for recalibration when setting up deterministic simulations. This value must be ≥ 3.
DeterministicFittingMethod	The fitting method for deterministic runs. Possible values: • **RecalibrateM0**—Recalibrate MeanReversionLevel.StartVal • **RecalibrateM0AndR0**—Recalibrate MeanReversionLevel.StartVal and ShortRate.StartVal • **RecalibrateM0AndMu**—Recalibrate MeanReversionLevel.StartVal and MeanReversionRate.Mu

Name	Description
	• **FullRecalibration**—Recalibrate MeanReversionLevel.StartVal, ShortRate.StartVal, and MeanReversionRate.Mu

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $$\begin{aligned}&\mathrm{CashTotalReturnIndex}(t)\\&\quad=\mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate.Value}(t-\Delta t)\Delta t)\end{aligned}$$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $$\mathrm{CashTotalReturn}(t)=\frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)}-1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\mathrm{AnnualisedCashTotalReturn}(t)=(1+\mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedShortRate	The annualized short rate.
ZCBP [CreditClass, Maturity, Seniority]	The zero-coupon bond price for the specified credit class and maturity.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate.
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},\mathrm{CompoundingFrequency},t)\\&\quad=\mathrm{CompoundingFrequency}\\&\quad\times\left\{(1+\mathrm{SpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},t))^{\frac{1}{\mathrm{CompoundingFrequency}}}-1\right\}\end{aligned}$$ And for continuous compounding: $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},\infty,t)\\&\quad=\ln(1+\mathrm{SpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},t))\end{aligned}$$
ForwardRate [CreditClass, Maturity, Seniority]	Simply compounded one year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity certain of the specified maturity (with one payment per annum).
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity.

Analysis tests

Name	Description
Initial Real Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Inflation Linked Zero Coupon Bond Martingale Test	Outputs estimated prices of inflation-linked zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

ShortRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models short rate dynamics as one-factor Vasicek process.

Input variables

Name	Description
Alpha	The rate of mean reversion.
Sigma	The volatility of the real short rate.
StartVal	The initial rate of the real short rate.

Outputs

Name	Description
Value	The real short rate is the continuously compounded real interest rate that applies to a very short period.

MeanReversionLevel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models mean reversion level dynamics as one-factor Vasicek process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the real mean reversion level.
Sigma	The volatility of the real mean reversion level.
Mu	The long-run mean of the mean reversion level.
StartVal	The initial value of the real mean reversion level.

Outputs

Name	Description
Value	The real mean reversion level. The initial value comes from **StartVal**, and future values are calculated from the two-factor Vasicek process.

TermPremium [ConstantTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The ConstantTermPremium model contains a single, constant market price of risk parameter, used in both the ShortRate and MeanReversionLevel models.

Input variables

Name	Description
Gamma	Interest rate market price of risk.

TermPremium [DualTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The DualTermPremium model contains two constant market price of risk parameters.

Input variables

Name	Description
ShortRateMPR	The market price of risk for the ShortRate model.
MeanReversionMPR	The market price of risk for the MeanReversionLevel model.

RealYieldCurve [TwoFactorBK]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The two-factor Black-Karasinski models the log of the short rate as a two-factor Vasicek process. The distribution is log-normal, hence the rates are strictly positive. Although the model is calibrated as a "best fit", it cannot exactly fit the initial term structure. For more information about a model that can achieve this fit, see RealYieldCurve [TwoFactorBKExt].

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	One-factor Black-Karasinski for modeling short rate dynamics.
MeanReversionLevel	One-factor Black-Karasinski for modeling mean reversion level dynamics.

Input variables

Name	Description	Condition
Gamma	Interest rate market price of risk.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
ShortRateCap	The maximum allowable value for the short rate.	
MeanReversionLevelCap	The maximum allowable value for the mean reversion level.	
InitialIndexValue	The base value for index outputs.	

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $$\begin{aligned}&\text{CashTotalReturnIndex}(t)\\&\quad=\text{CashTotalReturnIndex}(t-\Delta t)\exp(\text{ShortRate.Value}(t-\Delta t)\Delta t)\end{aligned}$$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $$\text{CashTotalReturn}(t)=\frac{\text{CashTotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t-\Delta t)}-1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t)=(1+\text{CashTotalReturn}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedShortRate	The annualized short rate.
ZCBP [CreditClass, Maturity, Seniority]	The zero-coupon bond price for the specified credit class and maturity.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate.
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\begin{aligned}&\text{CustomSpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},\text{CompoundingFrequency},t)\\&\qquad=\text{CompoundingFrequency}\\&\qquad\times\left\{(1+\text{SpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},t))^{\frac{1}{\text{CompoundingFrequency}}}-1\right\}\end{aligned}$$ And for continuous compounding: $$\begin{aligned}&\text{CustomSpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},\infty,t)\\&\qquad=\ln(1+\text{SpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},t))\end{aligned}$$
ForwardRate [CreditClass, Maturity, Seniority]	Simply compounded one year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity certain of the specified maturity (with one payment per annum).
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity.

Analysis tests

Name	Description
Initial Real Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Inflation Linked Zero Coupon Bond Martingale Test	Outputs estimated prices of inflation-linked zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

ShortRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Model short rate dynamics as one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion.
Sigma	The proportional volatility of the real short rate.
StartVal	The initial rate of the real short rate.

Outputs

Name	Description
Value	The real short rate is the continuously compounded real interest rate that applies to a very short period.

MeanReversionLevel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models mean reversion level dynamics as one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the real mean reversion level.
Sigma	The volatility of the real mean reversion level.
Mu	The mean of the log of the mean reversion level
StartVal	The initial value of the real mean reversion level.

Outputs

Name	Description
Value	The real mean reversion level. The initial value comes from **StartVal**, and future values are calculated from the two-factor Vasicek process

RealYieldCurve [TwoFactorBKExt]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The extended two-factor Black-Karasinski model allows a perfect fit to the initial term structure. Initial values for zero coupon bond prices are a direct model input (BondPrices). There is no external calibration required to fit the initial term structure. Beyond the maximum available bond term, the model extrapolates assuming a flat forward rate.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	Short rate dynamics are modeled as one-factor BK process.
MeanReversionLevel	Mean-reversion level dynamics are modeled as a one-factor BK process.
TermPremium	The term premium parameter is used to control the real-world expected short rate path and, hence, the risk premium on bonds. Possible models: • TermPremium [ConstantTermPremium] • TermPremium [TimeVaryingTermPremium]

Input variables

Name	Description
TreeTimestep	The length of the time step used in the binomial tree used to calculate bond prices. As this is decreased, the binomial tree becomes closer to a continuous-time model, at the expense of longer computation time, and greater required memory. See the following important note concerning memory requirements.
ShortRateTenor	The maturity of the short rate in the underlying 2FBK model. This parameter also dictates the constant increment of the terms of the **BondPrices**. This parameter must be equal to the **TreeTimestep** parameter. See the following important note concerning memory requirements.
BondPrices	Initial zero coupon bond prices at maturities that are spaced by the **ShortRateTenor**. In this case, the initial yield curve is fitted exactly. Beyond **Modelled Years**, extrapolation is used to calculate bond prices. Enter bond prices so that the continuously compounded displaced forward rates are strictly positive. For more information on how to transform bond prices into continuously compounded displaced forward rates, see the Scenario Generator Methodology Guide.
Modelled Years	This parameter is the maximum term at which bond prices are calculated to be exactly consistent with the model. Beyond this point, extrapolation is used to calculate bond prices, assuming a flat forward rate. Reducing Modelled Years often reduces the simulation time, but at the possible expense of accuracy. Also see the following important note concerning memory requirements.
ShortRateCap	The maximum allowable value for the short rate.
MeanReversionLevelCap	The maximum allowable value for the mean reversion level
InitialIndexValue	The base value for index outputs.
ShortRateDisplacement	To shift the modeled short rate away from a log normal model, you can enter a value for the short rate displacement. The software models the short rate as a strictly positive log-normal component r' and a displacement δ, such that the realized short rate is given by $r = r' - \delta$. If you enter a displacement of zero, this corresponds to a log normal model and in general the lowest realization of the short rate is given by $-\delta$. **Note** The volatility of the model is proportional to the level of r'. Therefore, for a given set of initial bond prices and model parameters, higher displacement will increase the volatility of model outputs. For more information about short rate displacement, see the Extended Two-Factor Black-Karasinski methodology.
ShortRateFloor	The floor on output short rates.
UseShortRateFloor	To use the short rate floor, select **True**.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $$\begin{aligned}&\mathrm{CashTotalReturnIndex}(t)\\&\quad=\mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate.Value}(t-\Delta t)\Delta t)\end{aligned}$$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $$\mathrm{CashTotalReturn}(t)=\frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)}-1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\mathrm{AnnualisedCashTotalReturn}(t)=(1+\mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
InitialYieldCurve [Maturity]	The initial yield curve in the form of zero coupon bond prices. This output is the same as the input **BondPrices** at the given maturity. Enter an integer between 1 and 120.
AnnualisedShortRate	The annualized short rate.
ZCBP [CreditClass, Maturity, Seniority]	The zero-coupon bond price for the specified credit class and maturity.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate.
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},\mathrm{CompoundingFrequency},t)\\&\quad=\mathrm{CompoundingFrequency}\\&\quad\times\left\{(1+\mathrm{SpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},t))^{\frac{1}{\mathrm{CompoundingFrequency}}}-1\right\}\end{aligned}$$ And for continuous compounding: $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},\infty,t)\\&\quad=\ln(1+\mathrm{SpotRate}(\mathrm{CreditClass},\mathrm{Maturity},\mathrm{Seniority},t))\end{aligned}$$
ForwardRate [CreditClass, Maturity, Seniority]	Simply compounded one year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity certain of the specified maturity (with one payment per annum).
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity.

Analysis tests

Name	Description
Initial Real Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Inflation Linked Zero Coupon Bond Martingale Test	Outputs estimated prices of inflation-linked zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

The memory requirements of the current implementation of the Ext2FBK model can easily be underestimated. The memory required for a single Ext2FBK nominal yield curve scales as a cubic polynomial of the number of levels on the tree. The number of levels is determined by the TreeTimestep and the Modelled Years.

ShortRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Short rate dynamics modeled as one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the short rate process.
Sigma	The proportional volatility of the real short rate.

Outputs

Name	Description
Value	The real short rate is the continuously compounded instantaneous real interest rate that applies to a very short period.
AnnualisedValue	The annualized real short rate.

MeanReversionLevel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Mean reversion level dynamics modeled as one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the real mean reversion level.
Sigma	The volatility of the real mean reversion level.

TermPremium [ConstantTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The ConstantTermPremium model contains a single, constant market price of risk parameter, used in both the ShortRate and MeanReversionLevel models.

Input variables

Name	Description	Conditions
Gamma	Interest rate market price of risk.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

TermPremium [TimeVaryingTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The time-varying term premium parameter set enables you to control the entire path of the short rate. It also contains the additional freedom of being able to control the path of the long rate using time dependency in the market price of risk parameter.

Input variables

Name	Description	Conditions
GammaArray	Time-dependent market price of risk parameter set.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

RealYieldCurve [AnnualGLMM, SemiAnnualGLMM, MonthlyGLMM]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A Heath, Jarrow, and Morton (HJM) model with LIBOR forward rates (simply compounded rates) and absolute volatilities. This implementation is a two-factor version and features deterministic volatility scaling factors for each initial rate, and a change of probability measure via the numeraire bond maturity term. For more information, see the MaturityOfNumeraireBond parameter of Simulation.

The model is also a displaced diffusion style model, with the displacement parameter fixed to ensure that the continuously compounded forward rates follow a Gaussian distribution.

The type of the model (Annual, SemiAnnual, or Monthly) must match the simulation time step.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate [VolatilityFactorMu]	The factor 1 volatility. The name 'ShortRate' is misleading for this model and used only to be consistent with other yield curve models. This name ensures that model can use the same correlation matrix entries as other interest rate models.
MeanReversionLevel [VolatilityFactorMu]	The factor 2 volatility. The name 'MeanReversionLevel' is misleading for this model and used only to be consistent with other yield curve models. This name ensures that model can use the same correlation matrix entries as other interest rate models.

Input variables

Name	Description
StartRates	The initial term structure of maturities of the simple forward rates that are uniformly increasing by a constant tenor. The tenor of the simple forward rates must match the simulation time step.

Name	Description
Gamma	Real interest rate "market price of risk". This parameter is only used in simulations run with UseRiskNeutralValuation parameter set to False, which corresponds to real world simulation. If the UseRiskNeutralValuation parameter is set to True, the parameter is 0 and is inactive.
ForwardRateCap	The maximum allowed forward rate to mitigate extreme upper rate percentile (exploding rates) for long simulation horizons and problematic scenarios. The cap is expressed as an absolute simple forward rate. Due to the Gaussian nature of this model, it is unlikely this parameter is required.
ForwardRateFloor	The smallest allowed forward rate to mitigate the size and or frequency of negative rates. The floor is expressed as an absolute simple forward rate.
LMM Modelled Years	This parameter provides a simple way to avoid unnecessary calculations in the latter part of the yield curve that might not be required anyway, and hence can be used to speed up the simulation. The parameter sets defining the yield curve model (start rates, volatility factors, and so on) are effectively truncated to a length (in years) of LMM Modelled Years. *For example*, if 20-year bond prices are to be simulated over a total of 40 years then LMM Modelled Years can be set to 60 without affecting calculated values. When calculations involve pricing of bonds with term longer than LMM Modelled Years, a constant forward rate extrapolation is used. A restriction is that LMM Modelled Years must be at least as long as the total simulation horizon (as defined by the simulation time steps).
InitialIndexValue	The base value for index outputs.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $$\begin{aligned}&\text{CashTotalReturnIndex}(t)\\&\quad=\text{CashTotalReturnIndex}(t-\Delta t)\exp(\text{ShortRate}(t-\Delta t)\Delta t)\end{aligned}$$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $$\text{CashTotalReturn}(t)=\frac{\text{CashTotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t-\Delta t)}-1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t)=(1+\text{CashTotalReturn}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The continuously compounded real interest rate that applies to a very short period. For the LMM models, this output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t)=\frac{-\ln(Z_N(Govt,\Delta t,t))}{\Delta t}$$ where Δt is the simulation time step.

Name	Description
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate}(t)) - 1$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$ And for continuous compounding: $\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$
ForwardRate [CreditClass, Maturity, Seniority]	The annualized forward rate applying over the tenor Δt equal to the length of the next simulation time step $[t, t + \Delta t]$, calculated using the formula: $\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{1}{\Delta t}\left(\frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + \Delta t, \text{Seniority}, t)} - 1\right)$
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the Frequency parameter. *For example*, for semi-annual par yields set Frequency =2. Calculated using the formula: $\text{ParYield}(\text{Frequency}, \text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{Frequency} \times (1 - Z_N(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))}{\sum_{s=1}^{\text{Frequency}\times\text{Maturity}} Z_N\left(\text{CreditClass}, \frac{s}{\text{Frequency}}, \text{Seniority}, t\right)}$ where Z_N are zero coupon bond prices based on this real yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Real Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.

Name	Description
Inflation Linked Zero Coupon Bond Martingale Test	Outputs estimated prices of inflation-linked zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

ShortRate [VolatilityFactorMu]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The factors represent a principal component of the forward rate yield curve covariance matrix.

Input variables

Name	Description
FactorVolatility	A parameter set with volatilities for this factor. The number of entries in the parameter set must match the number of start rates for the GLMM.

MeanReversionLevel [VolatilityFactorMu]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The factors represent a principal component of the forward rate yield curve covariance matrix.

Input variables

Name	Description
FactorVolatility	A parameter set with volatilities for this factor. The number of entries in the parameter set must match the number of start rates for the GLMM.

RealYieldCurve [TwoFactorHullWhite]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The TwoFactorHullWhite model is a two factor Gaussian short-rate model which can be initialized to fit an arbitrary time zero yield curve. The two factors are modeled as Ornstein-Uhlenbeck (also known as Vasicek) processes.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
InitialYieldCurve	The initial yield curve.
OneFactorVasicekHW1	A one-factor Vasicek model. Can be either of the following models: • OneFactorVasicekHW [OneFactorVasicekHW] • OneFactorVasicekHW [OneFactorVasicekTVTP]
OneFactorVasicekHW2	A one-factor Vasicek model. Can be either of the following models: • OneFactorVasicekHW [OneFactorVasicekHW] • OneFactorVasicekHW [OneFactorVasicekTVTP]

Input variables

Name	Description
InitialIndexValue	The base value for index outputs.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate}(t-\Delta t)\Delta t)$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)} - 1$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.

Name	Description
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t) = (1 + \text{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The continuously compounded real interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the simulation time step.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $$\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$$
ForwardRate [CreditClass, Maturity, Seniority]	The simply compounded one-year forward rate. Calculated using the formula: $$\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + 1, \text{Seniority}, t)}$$ where the +1 in the denominator is because this is a one-year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$$

Name	Description
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the Frequency parameter. *For example*, for semi-annual par yields set Frequency =2. Calculated using the formula: $$\begin{aligned}&\text{ParYield}(\text{Frequency}, \text{CreditClass}, \text{Maturity}, \text{Seniority}, t)\\&\quad= \frac{\text{Frequency} \times (1 - Z_N(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))}{\sum_{s=1}^{\text{Frequency}\times\text{Maturity}} Z_N\left(\text{CreditClass}, \frac{s}{\text{Frequency}}, \text{Seniority}, t\right)}\end{aligned}$$ where Z_N are zero coupon bond prices based on this real yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Real Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Inflation Linked Zero Coupon Bond Martingale Test	Outputs estimated prices of inflation-linked zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

InitialYieldCurve

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents the initial yield curve of the TwoFactorHullWhite model. The initial yield curve is specified with zero coupon bond prices at time zero. For more information about how the yield curve is interpolated, see the Scenario Generator Methodology Guide.

Input variables

Name	Description
InputYieldCurve	Specify the bond prices. For each maturity, enter the following values: • **Years**—The maturity time (measured in years) for the corresponding zero coupon bond. • **ZeroCouponBondPrice**—The zero coupon bond price for the specified maturity.

OneFactorVasicekHW [OneFactorVasicekHW]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents a one-factor Vasicek process with piecewise-constant time-dependent volatility, as used in the TwoFactorHullWhite real yield curve. The process has an initial value of zero and a risk-neutral mean reversion level of zero.

Input variables

Name	Description
RiskNeutralMeanReversionRate	The risk-neutral mean reversion rate of the stochastic process.
Volatility.Years	The time interval in years over which the corresponding volatility value applies.
Volatility.Volatility	The volatility of the stochastic process.
RealWorldMeanReversionRate	The real-world mean reversion rate of the stochastic process. Only required when running a real world simulation. **Note** To run a real-world simulation, set the UseRiskNeutralValuation parameter to False at the simulation level.
RealWorldMeanReversionLevel	The real-world mean reversion level. Only required when running a real world simulation. **Note** To run a real-world simulation, set the UseRiskNeutralValuation parameter to False at the simulation level.

Outputs

Name	Description
Value	The instantaneous value of the stochastic process.

OneFactorVasicekHW [OneFactorVasicekTVTP]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents a one-factor Vasicek process, used in the TwoFactorHullWhite real yield curve. The process has an initial value of zero and a risk-neutral mean reversion level of zero. For real-world simulations, the process has a smooth, time-varying term premium.

Input variables

Name	Description
MeanReversionRate	The mean reversion rate of the stochastic process.
Volatility	The volatility of the stochastic process.
Gamma	The time-varying market price of risk for the stochastic process.

Outputs

Name	Description
Value	The instantaneous value of the stochastic process.

RealYieldCurve [DeterministicYieldCurve]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A deterministic yield curve model. The model is evolved through time by realizing forward rates implied from the input yield curve, which is specified with zero coupon bond prices at time zero. For more details on how the Scenario Generator software interpolates the input yield curve, see the DeterministicYieldCurve methodology.

Input variables

Name	Description
InputYieldCurve	Specify the bond prices. For each maturity, enter the following values: • **Years**—The maturity time (measured in years) for the corresponding zero coupon bond. • **ZeroCouponBondPrice**—The zero coupon bond price for the specified maturity.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash, with a starting value of 1.0. $\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate}(t-\Delta t)\Delta t)$ where CashTotalReturnIndex(0) = 1.

Name	Description
CashTotalReturn	The total return of cash over the time step. $$\text{CashTotalReturn}(t) = \frac{\text{CashTotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t - \Delta t)} - 1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t) = (1 + \text{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The continuously compounded real interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the simulation time step.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $$\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$$
ForwardRate [CreditClass, Maturity, Seniority]	The simply compounded one-year forward rate. Calculated using the formula: $$\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + 1, \text{Seniority}, t)}$$ where the +1 in the denominator is because this is a one-year forward rate.

Name	Description
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$$
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the Frequency parameter. *For example*, for semi-annual par yields set Frequency =2. Calculated using the formula: $$\text{ParYield}(\text{Frequency}, \text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{Frequency} \times (1 - Z_N(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))}{\sum_{s=1}^{\text{Frequency}\times\text{Maturity}} Z_N\left(\text{CreditClass}, \frac{s}{\text{Frequency}}, \text{Seniority}, t\right)}$$ where Z_N are zero coupon bond prices based on this real yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Real Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Inflation Linked Zero Coupon Bond Martingale Test	Outputs estimated prices of inflation-linked zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

3.1.2 NominalYieldCurves

The Scenario Generator software supports multiple nominal yield curves for each economy. There is always one primary nominal yield curve in every economy, but there can be any number of added nominal yield curves, and all are housed in this container.

Note Assets priced using an added nominal yield curve do not exhibit martingale properties. They cannot be used for market-consistent valuation.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
NominalYieldCurve	Multi-factor forward and short rate models. This model is the core yield curve model, and can be changed to be any of the following variants: • NominalYieldCurve [ActuarialInterestRateModel] • NominalYieldCurve [TwoFactorVasicek] • NominalYieldCurve [TwoFactorBK] • NominalYieldCurve [TwoFactorBKExt] • NominalYieldCurve [LMMPlus] • NominalYieldCurve [AnnualLMM, SemiAnnualLMM, MonthlyLMM] • NominalYieldCurve [AnnualLMMPlus, SemiAnnualLMMPlus, MonthlyLMMPlus] • NominalYieldCurve [AnnualLMMPlusMFV, SemiAnnualLMMPlusMFV, MonthlyLMMPlusMFV] • NominalYieldCurve [TwoFactorHullWhite] • NominalYieldCurve [ThreeFactorExtendedCIR] • NominalYieldCurve [DeterministicYieldCurve] • NominalYieldCurve [YieldCurvePlusSpread] and [YieldCurveMinusSpread]

Addable submodels

Name	Description
NominalYieldCurve	Multi-factor forward and short rate models. Any one of: • NominalYieldCurve [ActuarialInterestRateModel] • NominalYieldCurve [TwoFactorVasicek] • NominalYieldCurve [TwoFactorBK] • NominalYieldCurve [TwoFactorBKExt] • NominalYieldCurve [LMMPlus] • NominalYieldCurve [AnnualLMM, SemiAnnualLMM, MonthlyLMM] • NominalYieldCurve [AnnualLMMPlus, SemiAnnualLMMPlus, MonthlyLMMPlus] • NominalYieldCurve [AnnualLMMPlusMFV, SemiAnnualLMMPlusMFV, MonthlyLMMPlusMFV] • NominalYieldCurve [TwoFactorHullWhite] • NominalYieldCurve [ThreeFactorExtendedCIR] • NominalYieldCurve [DeterministicYieldCurve] • NominalYieldCurve [YieldCurvePlusSpread] and [YieldCurveMinusSpread] These additional nominal yield curves can have any name, but see the calibration and precalibration notes available on the Customer Portal for any special naming conventions that might be a part of particular calibration files.

Input variables

Name	Description
CurrencyHedgeCurve	Specify the nominal yield curve that you want to use in currency hedging calculations for this economy.

NominalYieldCurve [ActuarialInterestRateModel]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An actuarial yield curve model, styled on the American Academy of Actuaries Generator model. Available when the simulation-level parameter UseRiskNeutralValuation is False.

Submodels

Name	Description
InitialYieldCurve	Represents the initial yield curve of the actuarial interest rate model. Can be the InitialYieldCurve [InitialParYields] or InitialYieldCurve [DeterministicYieldCurve] model.

Input variables

Name	Description
Modelled Years	The maximum size, in years, of the modeled yield curve. This value need not be the same as the duration of the last bond price from the simulation base time.
ShortRateMaturity	Maturity of the short rate.
LongRateMaturity	Maturity of the long rate.
Beta1	Mean reversion strength for the logarithm of the long rate.
Beta2	Mean reversion strength for the slope.
Beta3	Mean reversion strength for the logarithm of the volatility of the logarithm of the long rate.
Sigma2	Volatility of the slope.
Sigma3	Volatility of the stochastic volatility process.
Tau1	Mean reversion point for the long rate.
Tau2	Mean reversion point for the slope.
Tau3	Mean reversion point for the volatility of the logarithm of the long rate.
Psi	Steepness adjustment.
Phi	Slope tilting parameter.
Theta	Exponent for the spread volatility factor.

Name	Description
InitialVol	Initial volatility of the long rate.
Minr1	Soft floor on the long rate before random shock.
Minr2	Soft floor on the short rate.
Maxr1	Soft cap on the long rate before random shock.

Outputs

Name	Description
ShortRateValue	The value of the short rate process.
LongRateValue	The long rate of the model.
LongRateVolatilityValue	The model long rate volatility.
CashTotalReturnIndex	The total return index of cash, with a starting value of 1.0.
CashTotalReturn	The total return of cash over the time step.
AnnualisedCashTotalReturn	The annualized cash total return. $$\mathrm{AnnualisedCashTotalReturn}(t) = (1 + \mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The short rate.
AnnualisedShortRate	The annually compounded short rate.
ZCBP [CreditClass, Maturity, Seniority]	The zero-coupon bond price for the specified credit class and maturity.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate.
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \mathrm{CompoundingFrequency}, t)\\&\quad = \mathrm{CompoundingFrequency}\\&\quad \times \left\{ (1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))^{\frac{1}{\mathrm{CompoundingFrequency}}} - 1 \right\}\end{aligned}$$ And for continuous compounding: $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \infty, t)\\&\quad = \ln(1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))\end{aligned}$$
ForwardRate [CreditClass, Maturity, Seniority]	Simply compounded one year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity certain of the specified maturity (with one payment per annum).
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity.

Analysis tests

Name	Description
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.

InitialYieldCurve [InitialParYields]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Represents the initial yield curve of the actuarial interest rate model.

Input variables

Name	Description
InitialYieldCurve	The initial yield curve in terms of semiannual par yields. Takes the following parameters for each maturity: • **Years**—The maturity in years. • **SemiAnnualParYield**—The semiannual par yield.

InitialYieldCurve [DeterministicYieldCurve]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Represents the initial yield curve of the actuarial interest rate model.

Input variables

Name	Description
InitialYieldCurve	The initial yield curve in terms of zero coupon bond prices. Takes the following parameters for each maturity: • **Years**—The maturity in years. • **ZeroCouponBondPrice**—The zero coupon bond price.

NominalYieldCurve [TwoFactorVasicek]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The two-factor Vasicek model allows negative nominal interest rates. It has an imperfect correlation between different points on the yield curve, is mean-reverting and relatively simple and tractable.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	The short rate is modeled using a one-factor Vasicek model
MeanReversionLevel	The mean reversion rate is modeled using a one-factor Vasicek model
TermPremium	The market price of risk for the interest rate. Can be either TermPremium [ConstantTermPremium] or TermPremium [DualTermPremium].

Input variables

Name	Description	Conditions
InitialIndexValue	The base value for index outputs.	
DeterministicRecalibrationMaximumMaturity	The highest maturity of bond yield used for recalibration when setting up deterministic simulations. This value must be ≥ 3.	Enabled only if the simulation-level **StochasticRunType** parameter is **Deterministic**

Name	Description	Conditions
DeterministicFittingMethod	The fitting method for deterministic runs. Possible values: • **RecalibrateM0**—Recalibrate MeanReversionLevel.StartVal • **RecalibrateM0AndR0**—Recalibrate MeanReversionLevel.StartVal and ShortRate.StartVal • **RecalibrateM0AndMu**—Recalibrate MeanReversionLevel.StartVal and MeanReversionRate.Mu • **FullRecalibration**—Recalibrate MeanReversionLevel.StartVal, ShortRate.StartVal, and MeanReversionRate.Mu	Enabled only if the simulation-level **StochasticRunType** parameter is **Deterministic**

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate.Value}(t-\Delta t)\Delta t)$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)} - 1$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $\mathrm{AnnualisedCashTotalReturn}(t) = (1 + \mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $\mathrm{AnnualisedShortRate}(t) = \exp(\mathrm{ShortRate.Value}(t)) - 1$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $\mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \left(\frac{1}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}\right)^{\frac{1}{\mathrm{Maturity}}} - 1$

Name	Description
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \mathrm{CompoundingFrequency}, t)\\&\quad = \mathrm{CompoundingFrequency}\\&\quad \times \left\{ (1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))^{\frac{1}{\mathrm{CompoundingFrequency}}} - 1 \right\}\end{aligned}$$ And for continuous compounding: $$\begin{aligned}&\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \infty, t)\\&\quad = \ln(1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))\end{aligned}$$
ForwardRate [CreditClass, Maturity, Seniority]	The simply compounded one-year forward rate. Calculated using the formula: $$\begin{aligned}&\mathrm{ForwardRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)\\&\quad = \frac{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity} + 1, \mathrm{Seniority}, t)}\end{aligned}$$ where the +1 in the denominator is because this is a one-year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\begin{aligned}&\mathrm{AnnuityPrice}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)\\&\quad = \sum_{\tau=1}^{\mathrm{Maturity}} \mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority}, t)\end{aligned}$$
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, \mathrm{CreditClass}, \tau, \mathrm{Seniority}) = f\,\frac{1 - \mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})}{\sum_{n=1}^{f\times\tau} \mathrm{ZCBP}\left(\mathrm{CreditClass}, \frac{n}{f}, \mathrm{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Zero Coupon Bond Martingale Test	Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.

Name	Description
Local Currency Zero Coupon Bond Martingale Test	Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.

ShortRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Input variables

Name	Description
Alpha	The rate of mean reversion.
Sigma	The volatility of the nominal short rate.
StartVal	The initial value of the nominal short rate.

Outputs

Name	Description
Value	The continuously compounded nominal short rate is the nominal interest rate that applies to a very short period.

MeanReversionLevel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Input variables

Name	Description
Alpha	The rate of mean reversion of the nominal mean reversion level.
Sigma	The volatility of the nominal mean reversion level.
Mu	The long-run mean of the mean reversion level.
StartVal	The initial value of the nominal mean reversion level.

Outputs

Name	Description
Value	The mean reversion level. The initial value comes from **StartVal**, and future values are calculated from the two-factor Vasicek process.

TermPremium [ConstantTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The ConstantTermPremium model contains a single, constant "market price of risk" parameter, used in both the ShortRate and MeanReversionLevel models.

Input variables

Name	Description	Conditions
Gamma	Interest rate market price of risk.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

TermPremium [DualTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The DualTermPremium model contains two constant market price of risk parameters.

Input variables

Name	Description
ShortRateMPR	The market price of risk for the ShortRate model.
MeanReversionMPR	The market price of risk for the MeanReversionLevel model.

NominalYieldCurve [TwoFactorBK]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The two-factor Black-Karasinski models the log of the short rate as a two-factor Vasicek process. The distribution is log-normal, hence the rates are strictly positive. Although the model is calibrated as a "best fit", it cannot exactly fit the initial term structure. For more information about a model that can achieve this fit, see NominalYieldCurve [TwoFactorBKExt].

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	Short rate dynamics are modeled as one-factor Black-Karasinski process.
MeanReversionLevel	Mean-reversion level dynamics are modeled as a one-factor Black-Karasinski process.

Input variables

Name	Description
Gamma	Interest rate market price of risk.
ShortRateCap	The maximum allowable value for the short rate.
MeanReversionLevelCap	The maximum allowable value for the mean reversion level.
InitialIndexValue	The base value for index outputs.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $$\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate.Value}(t-\Delta t)\Delta t)$$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $$\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)} - 1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\mathrm{AnnualisedCashTotalReturn}(t) = (1+\mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $$\mathrm{AnnualisedShortRate}(t) = \exp(\mathrm{ShortRate.Value}(t)) - 1$$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \left(\frac{1}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}\right)^{\frac{1}{\mathrm{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \mathrm{CompoundingFrequency}, t) = \mathrm{CompoundingFrequency} \times \left\{(1+\mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))^{\frac{1}{\mathrm{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \infty, t) = \ln(1+\mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))$$
ForwardRate [CreditClass, Maturity, Seniority]	The annualized forward rate applying over the tenor Δt equal to the length of the next simulation time step $[t, t+\Delta t]$, calculated using the formula: $$\mathrm{ForwardRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \frac{1}{\Delta t}\left(\frac{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}+\Delta t, \mathrm{Seniority}, t)} - 1\right)$$

Name	Description
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\mathrm{AnnuityPrice}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \sum_{\tau=1}^{\mathrm{Maturity}} \mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority}, t)$$
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, \mathrm{CreditClass}, \tau, \mathrm{Seniority}) = f\frac{1-\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})}{\sum_{n=1}^{f\times\tau}\mathrm{ZCBP}\left(\mathrm{CreditClass}, \frac{n}{f}, \mathrm{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Zero Coupon Bond Martingale Test	Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Local Currency Zero Coupon Bond Martingale Test	Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year.

Name	Description
	Note If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.

ShortRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Model the short rate using a one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the nominal short rate.
Sigma	The proportional volatility of the nominal short rate.
StartVal	The initial value of the nominal short rate. The Extended Two-FactorBK interest rate model does not use this parameter.

Outputs

Name	Description
Value	The continuously compounded nominal short rate is the nominal interest rate that applies to a very short period. In the TwoFactorBK model, this output corresponds to the one-year nominal spot rate. The initial value comes from **StartVal**, and future values are calculated from the Two-Factor Black-Karasinski equations.

MeanReversionLevel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the mean reversion level dynamics using a one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the nominal mean reversion level.
Sigma	The volatility of the nominal mean reversion level.
Mu	The mean of the log of the nominal short rate. The Extended two-factor BK interest rate model does not use this parameter.
StartVal	The initial value of the nominal mean reversion level. The Extended two-factor BK interest rate model does not use this parameter.

Outputs

Name	Description
Value	The nominal mean reversion level.

NominalYieldCurve [TwoFactorBKExt]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The extended two-factor Black-Karasinski model allows a perfect fit to the initial term structure. Initial values for zero coupon bond prices are a direct model input (BondPrices). There is no external calibration required to fit the initial term structure. Beyond the maximum available bond term, the model extrapolates assuming a flat forward rate.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	Short rate dynamics are modeled as one-factor BK process.
MeanReversionLevel	Mean-reversion level dynamics are modeled as a one-factor BK process.
TermPremium	The term premium parameter is used to control the real-world expected short rate path and, hence, the risk premium on bonds. Possible values: • TermPremium [ConstantTermPremium] • TermPremium [TimeVaryingTermPremium]

Name	Description
	• TermPremium [StrongMeanReversion]

Input variables

Name	Description	Conditions
TreeTimestep	The length of the time step used in the 2D binomial tree used to calculate bond prices. As this parameter is decreased, the binomial tree becomes closer to a continuous-time model, at the expense of longer computation time, and greater required memory. Possible values: **1m**, **3m**, **6m**, **1y**, and **Mixed**. See the following important note concerning memory requirements.	**Mixed** can only be used if **UseRiskNeutralValuation** is set to **True**.
MixedTreeTimesteps	Specify the number of time steps of each length used in the 2D binomial tree to calculate bond prices when the TreeTimestep is **Mixed**. Where the tree time steps specified total less than Modelled Years, the tree will be completed using annual steps. When the tree time steps specified are more granular than the current simulation time step, the more granular tree time steps will be converted to match the simulation time step. *For example*, if the simulation time step is quarterly, any months specified in the parameter set will be converted to quarters in the binomial tree. This also means that if all simulation time steps are annual, the binomial tree will be built using annual tree time steps, regardless of what is specified. The cumulative aggregate of the monthly, quarterly, and semiannual tree layers specified here must equate to an integer number of years.	Enabled only if **TreeTimestep** is set to **Mixed**.
ShortRateTenor	This input relates to the input values in the **Bond Prices** parameter set and specifies the increment in the term of these zero coupon bond prices. *For example*, ShortRateTenor=3m would mean that the **Bond Prices** parameter set will be interpreted as containing quarterly zero coupon bond prices. **ShortRateTenor** must be equal to **TreeTimestep**, except when **TreeTimestep** is set to **Mixed**. See the following important note concerning memory requirements.	
Bond Prices	Initial zero coupon bond prices at maturities that are spaced by the **ShortRateTenor**. In this case, the initial yield curve is fitted exactly out to a term of **Modelled Years**. Longer term bond prices are obtained by extrapolation. Enter bond prices so that the continuously compounded displaced forward rates are strictly positive. For more information on how to transform bond prices into continuously compounded displaced forward rates, see the Scenario Generator Methodology Guide.	
Modelled Years	This parameter is the maximum term at which bond prices are calculated to be exactly consistent with the model. Beyond this point, extrapolation is used to calculate bond prices, assuming a flat forward rate. Reducing **Modelled Years** often reduces the simulation time, but at the possible expense of accuracy. Also see the following important note concerning memory requirements.	
ShortRateCap	The maximum allowable value for the short rate.	
MeanReversionLevelCap	The maximum allowable value for the mean reversion level.	
InitialIndexValue	The base value for index outputs.	
ShortRateDisplacement	To shift the modeled short rate away from a log normal model, you can enter a value for the short rate displacement. The software models the short rate as a strictly positive log-normal component r' and a	

Name	Description	Conditions
	displacement δ, such that the realized short rate is given by $r = r' - \delta$. If you enter a displacement of zero, this corresponds to a log normal model and in general the lowest realization of the short rate is given by $-\delta$. **Note** The volatility of the model is proportional to the level of r'. Therefore, for a given set of initial bond prices and model parameters, higher displacement increases the volatility of model outputs. For more information about short rate displacement, see the Extended Two-Factor Black-Karasinski methodology.	
ShortRateFloor	The floor on output short rates.	Enabled only if **UseShortRateFloor** is **True**.
UseShortRateFloor	To use the short rate floor, select **True**.	
PsiTolerance	The tolerance of the numerical algorithm that is used when calculating the phi function, which governs the precise fit to the initial yield curve.	

Note The memory requirements of the current implementation of the Ext2FBK model can easily be underestimated, particularly with the option to change the TreeTimestep and ShortRateTenor parameters to be less than one year. The memory required for a single Ext2FBK nominal yield curve scales as a cubic polynomial of the number of levels on the tree. The number of levels is determined by the TreeTimestep and the Modelled Years. Choosing the Mixed TreeTimestep mode means that the tree operates in a slightly different way and in most cases has a lower memory footprint.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $$\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate.Value}(t-\Delta t)\Delta t)$$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $$\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)} - 1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\mathrm{AnnualisedCashTotalReturn}(t) = (1 + \mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.

Name	Description
InitialYieldCurve [Maturity]	The initial yield curve in the form of zero coupon bond prices. This output is the same as the input **BondPrices** at the given maturity. Enter an integer between 1 and 120.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$ And for continuous compounding: $\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$
ForwardRate [CreditClass, Maturity, Seniority]	The annualized forward rate applying over a tenor equal to the time step, Δ*t*, used in the tree. It is calculated using the formula: $\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + 1, \text{Seniority}, t)} - 1$
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $\text{ParYield}(f, \text{CreditClass}, \tau, \text{Seniority}) = f \frac{1 - \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})}{\sum_{n=1}^{f \times \tau} \text{ZCBP}\left(\text{CreditClass}, \frac{n}{f}, \text{Seniority}\right)}$ where: • f is the frequency. • τ is the maturity. • $\text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Name	Description
TimeStepPhi [Index]	The time step phi values over the corresponding tree node interval.
X	The value of the X state variable.
Y	The value of the Y state variable

Analysis tests

Name	Description
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel]	Outputs time-zero swaption prices and implied volatilities with swaption maturities corresponding to each time step. The underlying swap has an annual payment frequency. Fill the following fields: • **SwaptionType**—Payer or Receiver. • **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. Possible values: ◦ **ForwardStrike1**—The software calculates the swaption strike as the corresponding forward swap rate multiplied by the input StrikeRate.

Name	Description
	◦ **ForwardStrike2**—The software calculates the swaption strike as the corresponding forward swap rate plus the input StrikeRate. ◦ **AbsoluteStrike**—The swaption strike equals the input StrikeRate. • **StrikeRate**—This parameter, together with the StrikeType determines the swaption strike rate. • **SwapTenor**—The tenor of the underlying swap. • **ImpliedVolatilityType**—The basis by which the implied volatility is reported. Possible values: ◦ **Lognormal**—The software quotes the volatility on a "displaced log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement, then a standard log-normal volatility is reported. ◦ **Normal**—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate. • **Displacement**—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal. • **SignificanceLevel**—The significance level used for reporting the confidence interval for estimated swaption implied volatility. The preset value, 0.05, corresponds to a 95% confidence interval.
Local Currency Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel]	A local currency version of the Swaption Test (described above) which uses the local economy's nominal yield curve to calculate prices (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Zero Coupon Bond Martingale Test	Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Local Currency Zero Coupon Bond Martingale Test	Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.

ShortRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Short rate dynamics modeled as a one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the short rate process.
Sigma	The proportional volatility of the nominal short rate.

Outputs

Name	Description
Value	The continuously compounded nominal short rate is the nominal interest rate that applies to a very short period. In the TwoFactorBKExt model, this output corresponds to the continuously compounded nominal spot rate for the first time period equal to the ShortRateTenor input. Hence it is derived from the risk free zero coupon bond price of this maturity: $\text{Value}(t) = \dfrac{-\ln(Z_N(\text{Govt}, \text{ShortRateTenor}, t))}{\text{ShortRateTenor}}$ The initial value is specified by the calibration and future values are governed by the dynamics of the Two-Factor Black Karasinski model.
AnnualisedValue	The annually compounded short rate. Calculated using the equation $\text{AnnualisedValue}(t) = \exp(\text{Value}(t)) - 1$

MeanReversionLevel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the mean reversion level dynamics using a one-factor Black-Karasinski process.

Input variables

Name	Description
Alpha	The rate of mean reversion of the nominal mean reversion level.
Sigma	The volatility of the nominal mean reversion level.

TermPremium [ConstantTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The ConstantTermPremium model contains a single, constant "market price of risk" parameter, used in both the ShortRate and MeanReversionLevel models.

Input variables

Name	Description	Conditions
Gamma	Interest rate market price of risk.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

TermPremium [TimeVaryingTermPremium]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The time-varying term premium parameter set enables you to control the entire path of the short rate. Italso enables you to control the path of the long rate using time dependency in the market price of risk parameter.

Input variables

Name	Description	Conditions
GammaArray	Time-dependent market price of risk parameter set.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

TermPremium [StrongMeanReversion]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The time-varying term premium parameter set enables you to control the entire path of the short rate. It also enables you to control the path of the long rate using time dependency in the market price of risk parameter.

Use of strong mean reversion in the model enables the ϕ function to mean revert more quickly to its long-term level, and allows stable, economically plausible rate distributions over projection horizons.

Input variables

Name	Description	Condition
GammaArray	Time-varying term premium parameter set.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
StrongMeanReversionType	The type of strong mean reversion that you want to use. Possible values: • **None**—The software does not use strong mean reversion. Equivalent to using the TimeVaryingTermPremium model. • **Exponential**—Enables the ϕ function to exponentially mean-revert more quickly to its long-term level. • **Linear**—Enables the ϕ function to linearly mean-revert more quickly to its long-term level.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
StrongMeanReversionSpeed	The speed of reversion of each point on the ϕ function to a mean reversion level given by the StrongMeanReversionLevel, as a positive or zero value.	Enabled only if **StrongMeanReversionType** is **Exponential** or **Linear**.

Name	Description	Condition
UseDefaultReversionLevel	Select whether to use the preset StrongMeanReversionLevel. Possible values: • **True**—The software calculates the StrongMeanReversionLevel as the average of the last 10 ϕ values from the initial yield curve set up in the simulation. If the yield curve has fewer than 10 prices, then the software calculates the StrongMeanReversionLevel as the average of the ϕ values available. • **False**—Manually define the StrongMeanReversionLevel.	Enabled only if **StrongMeanReversionType** is **Exponential** or **Linear**.
StrongMeanReversionLevel	The mean reversion level for the ϕ function.	Enabled only if **UseDefaultReversionLevel** is **False**.

NominalYieldCurve [LMMPlus]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A Heath, Jarrow, and Morton (HJM) model with LIBOR forward rates (simply compounded rates). This implementation is a two-factor version, and features a stochastic volatility scaling factor, constant displacement, change of probability measure via the numéraire bond maturity term, and a Brownian bridge discretization applied to the volatility (variance) process.

For more information about the change of probability measure, see the MaturityOfNumeraireBond parameter of Simulation.

Note This model is not supported when UseRiskNeutralValuation is set to False, or for use with Derivatives or ManagedPortfolio models.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	The factor 1 volatility. The name 'ShortRate' is misleading for this model and only used to be consistent with other yield curve models. This name means that the model can use the same correlation matrix entries as other interest rate models.
MeanReversionLevel	The factor 2 volatility. The name 'MeanReversionLevel' is misleading for this model and only used to be consistent with other yield curve models. This name means that the model can use the same correlation matrix entries as other interest rate models.
Volatility	Volatility is a stochastic variable which is described by the square root of the Cox-Ingersoll-Ross (CIR) process. The CIR process models the instantaneous variance and is correlated with the interest rate factor shocks of the forward rates using the Correlation parameter Embedded image.

Input variables

Name	Description	Conditions
StartRates	The initial term structure of maturities of the simple forward rates that are uniformly increasing by monthly tenor. Initial forward rates must be greater than or equal to the negative equivalent of the value entered for the **ForwardRateDisplacement**. A restriction is that modeled years (the minimum of the LMM Modelled Years and the horizon of the StartRates) must be at least as long as the total simulation horizon (as defined by the simulation time steps).	
Gamma	Nominal interest rate "market price of risk".	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**. If **UseRiskNeutralValuation** is **True**, then **Gamma** is 0.
BoundingMethod	The bounding method for forward rates. Use this parameter to mitigate forward rate explosions (extreme upper rate percentiles which can be observed for long simulation horizons) by using cap and floor levels, by freezing forward rate paths that are greater than or less than set thresholds, or both. Possible values: • **None**—The simulation evolves forward rates without applying a bounding method. • **Cap/Floor**—The simulation applies a cap and floor on forward rates. If any forward rate exceeds the **ForwardRateCap** value, then it is reduced to the level of the cap. If any forward rate is less than the **ForwardRateFloor** value, then it is increased to the level of the floor. • **Freeze**—The simulation applies path freezing when the threshold is exceeded. If, for any given trial and time step, any forward rate is greater than the **UpperPathFreezeThreshold** value or less than the **LowerPathFreezeThreshold** value, then for that trial and from the next time step onwards the forward rates evolve deterministically. • **Cap/Floor and Freeze**—The simulation applies the **Cap/Floor** and **Freeze** methods simultaneously.	
ForwardRateCap	The maximum allowed forward rate to mitigate extreme upper rate percentile (exploding rates) for long simulation horizons and problematic scenarios. The simulation applies this cap to forward rates when you set the **BoundingMethod** to **Cap/Floor** or **Cap/Floor and Freeze**. The cap is expressed as an absolute simple forward rate.	Enabled only if **BoundingMethod** is **Cap/Floor** or **Cap/Floor and Freeze**.
ForwardRateFloor	The smallest allowed forward rate to mitigate the size and or frequency of negative rates. The simulation applies this floor to forward rates when you set the **BoundingMethod** to **Cap/Floor** or **Cap/Floor and Freeze**. The floor is expressed as an absolute simple forward rate.	Enabled only if **BoundingMethod** is **Cap/Floor** or **Cap/Floor and Freeze**.
UpperPathFreezeThreshold	The upper threshold that triggers a path freeze in the simulation, used when you select **Freeze** or **Cap/Floor and Freeze** as the **BoundingMethod**. The threshold is expressed as an absolute simple forward rate.	Enabled only if BoundingMethod is **Freeze** or **Cap/Floor and Freeze**.
LowerPathFreezeThreshold	The lower threshold that triggers a path freeze in the simulation, used when you select **Freeze** or **Cap/Floor and Freeze** as the **BoundingMethod**. The threshold is expressed as an absolute simple forward rate.	Enabled only if BoundingMethod is **Freeze** or **Cap/Floor and Freeze**.
LMM Modelled Years	This parameter provides a simple way to avoid unnecessary calculations in the latter part of the yield curve that might not be required anyway, and hence can be used to speed up the simulation.	

Name	Description	Conditions
	The parameter sets defining the yield curve model (start rates, volatility factors, and so on) are effectively truncated to a length (in years) of LMM Modelled Years. *For example*, if 20-year bond prices are to be simulated over a total of 40 years then LMM Modelled Years can be set to 60 without affecting calculated values. When calculations involve pricing of bonds with term longer than LMM Modelled Years, a constant forward rate extrapolation is used. A restriction is that modeled years (the minimum of the LMM Modelled Years and the horizon of the StartRates) must be at least as long as the total simulation horizon (as defined by the simulation time steps).	
ForwardRateDisplacement	This parameter controls the size of the deviation of the model from the *geometric* proportional volatility. The displacement must lie in the interval $[0, 1/\tau]$, where τ denotes the longest LIBOR tenor of the model. *For example*, if all tenors for the forward rate are equal to 1/12 then you cannot enter a displacement greater than 12 (1200%). A displacement of 0 corresponds to the geometric (log-normal) setup of this model, whereas a displacement of 12 corresponds to a Gaussian short-rate type model.	
NumberOfSubdivisions	The number of subdivisions occurring per year for Brownian Bridge submodels. Where the time step length is less than annual, the subdivisions are prorated according to the time step length and then rounded up.	
DriftCalculationsPerYear	The number of drift calculations that occur per year. Where the time step length is less than annual, the number of drift calculations in that time step is prorated according to the time step length and then rounded up.	
SimulationCompounding	The compounding convention to use when calculating the simulated forward rates. Possible values: • **TimestepImplied**—The tenor and the compounding of simulated forward rates is as per the length of the current time step of the simulation. • **Monthly**—The tenor and the compounding of simulated forward rates is monthly, independently of the length of the time step.	
InitialIndexValue	The base value for index outputs.	

Outputs

Name	Description
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$

Name	Description
CashTotalReturn	The total return of cash over the time step. $$\text{CashTotalReturn}(t) = \frac{\text{CashTotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t-\Delta t)} - 1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t) = (1 + \text{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
CashTotalReturnIndex	The total return index of cash. $$\begin{aligned}&\text{CashTotalReturnIndex}(t)\\&\quad = \text{CashTotalReturnIndex}(t-\Delta t)\exp(\text{ShortRate}(t-\Delta t)\Delta t)\end{aligned}$$ where CashTotalReturnIndex(0) = InitialIndexValue.
ForwardAnnuityPrice [Maturity, AnnuityTenor, AnnuityPaymentFrequency]	The price of a forward-starting annuity. Fill the following fields: • **Maturity**—The time until the annuity starts. • **AnnuityTenor**—The length of time over which annuity payments are made. • **AnnuityPaymentFrequency**—The payment frequency of the annuity.
ForwardRate [CreditClass, Maturity, Seniority]	The annualized forward rate applying over the tenor Δt equal to the length of the next simulation time step $[t, t+\Delta t]$, calculated using the formula: $$\begin{aligned}&\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)\\&\quad = \frac{1}{\Delta t}\left(\frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}+\Delta t, \text{Seniority}, t)} - 1\right)\end{aligned}$$
ForwardSwapRate [Maturity, SwapTenor, SwapPaymentFrequency]	The forward swap rate. Fill the following fields: • **Maturity**—The time until the underlying swap starts. • **SwapTenor**—The tenor of the underlying swap. • **SwapPaymentFrequency**—The payment frequency of the underlying swap.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\text{ParYield}(f, \text{CreditClass}, \tau, \text{Seniority}) = f\frac{1-\text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})}{\sum_{n=1}^{f\times\tau}\text{ZCBP}\left(\text{CreditClass}, \frac{n}{f}, \text{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Name	Description
ShortRate	The continuously compounded nominal interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the length of the next simulation time step $[t, t+\Delta t]$.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$$

SwaptionImpliedVolatility [SwaptionType, StrikeType, StrikeRate, Maturity, SwapTenor, ImpliedVolatilityType, Displacement]	The implied volatility of a swaption with the specified features. The underlying swap has an annual payment frequency. Fill the following fields:
	• **SwaptionType**—Payer or Receiver.
	• **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. Possible values:
	  ◦ **ForwardStrike1**—The software calculates the swaption strike as the corresponding ForwardSwapRate multiplied by the input StrikeRate.
	  ◦ **ForwardStrike2**—The software calculates the swaption strike as the corresponding ForwardSwapRate plus the input StrikeRate.
	  ◦ **AbsoluteStrike**—The swaption strike equals the input StrikeRate.
	• **StrikeRate**—This parameter, together with the StrikeType determines the swaption strike rate.
	• **Maturity**—The maturity of the swaption, which must be an integer.
	• **SwapTenor**—The tenor of the underlying swap.
	• **ImpliedVolatilityType**—The basis by which the swaption implied volatility is reported. Possible values:
	  ◦ **Lognormal**—The software quotes the volatility on a "displaced Log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement the software reports a standard log-normal volatility.
	  ◦ **Normal**—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate.
	• **Displacement**—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal.

SwaptionPrice [SwaptionType, StrikeType, StrikeRate, Maturity, SwapTenor]	The price of a swaption with the specified features. The underlying swap has an annual payment frequency. Fill the following fields: • **SwaptionType**—**Payer** or **Receiver**.

Name	Description
	• **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. Possible values: ◦ **ForwardStrike1** —The software calculates the swaption strike as the corresponding ForwardSwapRate multiplied by the input StrikeRate. ◦ **ForwardStrike2**—The software calculates the swaption strike as the corresponding ForwardSwapRate plus the input StrikeRate. ◦ **AbsoluteStrike**—The swaption strike equals the input StrikeRate. • **StrikeRate**—This parameter, together with the StrikeType determines the swaption strike rate. • **Maturity**—The maturity of the swaption, which must be an integer. • **SwapTenor**—The tenor of the underlying swap.
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on SimulationCompounding. Let $0 = t_0 < t_1 < \cdots < t_M$ denote the – possibly mixed monthly, quarterly, semi-annual, and annual – simulation times given in Simulation.Timesteps, and let $L(n, t_m)$ denote the forward rate for the interval $[t_n, t_{n+1})$ simulated at time step t_m . If SimulationCompounding is TimestepImplied, ZCBP[Govt,Maturity,Seniority] at time step t_m is $$\frac{1}{\left(1+\left(t_{n(t')+1}-t_{n(t')}\right)\cdot L(n(t'),t_m)\right)^{\frac{t'-t_{n(t')}}{t_{n(t')+1}-t_{n(t')}}}\cdot\prod_{n=m}^{n(t')-1}(1+(t_{n+1}-t_n)\cdot L(n,t_m))}$$ where $t' = t_m + \text{Maturity}$ and $n(t') = \max\{n \in \mathbb{N}: t_{n(t')} < t'\}$. If SimulationCompounding is Monthly, $$\text{ZCBP[Govt,Maturity,Seniority]} = \frac{1}{\left(1+\frac{L\left(n(t'),t_m\right)}{12}\right)^{12\cdot\left(t'-t_{n(t')}\right)}\cdot\prod_{n=m}^{n(t')-1}\left(1+\frac{L(n,t_m)}{12}\right)^{12\cdot(t_{n+1}-t_n)}}.$$ For other credit classes, see the *Scenario Generator Methodology Guide* for the derivation of credit-risky zero coupon bond prices from the risk-free zero coupon bond price.

Analysis tests

Name	Description
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td>Forward Swap Rate Test [SwapTenor, Frequency]</td><td>Outputs time-zero forward swap rates for underlying swaps starting at each time step. Fill the following fields:
SwapTenor—The tenor of the underlying swap.
Frequency—The payment frequency of the underlying swap.</td></tr>
<tr><td>Initial Nominal Yield Curve [MaximumMaturityYears]</td><td>Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.</td></tr>
<tr><td>Swap Market Instrument Test [Name, Term, Frequency]</td><td>Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually.
After selecting the test, enter the following values for each swap:
Name—A name for the swap.
Term—The number of years of the swap.
Frequency—The number of swap payments per year.
Note If you enter multiple swaps, each appears as a separate line in the Selected list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the Write header row and Folder values from the first swap that you define.</td></tr>
<tr><td>Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]</td><td>Outputs time-zero swaption prices and implied volatilities with swaption maturities corresponding to each time step. The underlying swap has an annual payment frequency. Fill the following fields:
SwaptionType—Payer or Receiver.
StrikeType—This parameter, together with the StrikeRate, defines the strike of the option. Possible values:
ForwardStrike1 —The software calculates the swaption strike as the corresponding forward swap rate multiplied by the input StrikeRate.
ForwardStrike2—The software calculates the swaption strike as the corresponding forward swap rate plus the input StrikeRate.
AbsoluteStrike—The swaption strike equals the input StrikeRate.
StrikeRate—This parameter, together with the StrikeType determines the swaption strike rate.
SwapTenor—The tenor of the underlying swap.
ImpliedVolatilityType—The basis by which the implied volatility is reported. Possible values:
Lognormal —The software quotes the volatility on a "displaced log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement, then a standard log-normal volatility is reported.
Normal—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate.
Displacement—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal.
SignificanceLevel—The significance level used for reporting the confidence interval for estimated swaption implied volatility. The preset value, 0.05, corresponds to a 95% confidence interval.
IncludeAnalyticVol—To include analytical (model) volatility and price, select True.
Note This test gives a value for integer maturities. For non-integer maturities, analytic implied volatilities are NaN.</td></tr>
<tr><td>Local Currency Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]</td><td>A local currency version of the Swaption Test (described above) which uses the local economy's nominal yield curve to calculate prices (instead of the base economy of the simulation).
The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.</td></tr>
</table>

Name	Description
Zero Coupon Bond Martingale Test	Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Local Currency Zero Coupon Bond Martingale Test	Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.

VolatilityFactor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The factors represent a principal component of the forward rate yield curve covariance matrix.

Input variables

Name	Description
FactorVolatility	A parameter set with volatilities for this factor. The number of entries in the parameter set must match the number of start rates for the LMMPlus.

Volatility

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Volatility is a stochastic variable which is described by the square root of the Cox-Ingersoll-Ross (CIR) process. The CIR process models the instantaneous variance and is correlated with the interest rate factor shocks of the forward rates using the Correlation parameter ρ. For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Input variables

Name	Description	Conditions
MeanReversionRate	The mean reversion rate of the underlying stochastic variance process.	
Volatility	The volatility of the underlying stochastic variance process.	
MeanReversionLevel	The mean reversion level of the underlying stochastic variance process.	

Name	Description	Conditions
RiskNeutralMeanReversionRate	The risk neutral rate of mean reversion of the underlying stochastic variance process.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMeanReversionLevel	The risk neutral mean reversion level of the underlying stochastic variance process.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
InitialValue	The initial value of the underlying stochastic variance process.	
Correlation	The correlation between the combined factor shocks of the forward rate process and the underlying stochastic variance process.	

Outputs

Name	Description
Volatility	The square root of the value of the stochastic variance process.
SwaptionImpliedVolatility [StrikeRate, StrikeType, Maturity, Tenor]	This output calculates the implied volatility (using Black 76 model assumptions) of a swaption with the specified features and an annual swap frequency. Enter the following parameters: • **StrikeRate**—This parameter, together with the StrikeType defines the strike of the option. See below for details. • **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. • **Maturity**—The maturity of the option in years. • **Tenor**—The tenor (total term) of the underlying swap contract. The strike of the option is determined by the StrikeRate, StrikeType, and the prevailing yield curve via the equilibrium forward swap rate. The StrikeType governs how this is determined as follows: • **ForwardStrike1**: The strike of the option is derived in a multiplicative sense as follows: $\text{Strike} = \text{EquilibriumForwardSwapRate}(t) \times \text{StrikeRate}$ where EquilibriumForwardSwapRate(*t*) is the fixed rate that is required to price the forward starting swap at zero, based on the yield curve at this time step. This means that for a forward at-the-money swaption you enter a StrikeRate of 1.0. StrikeRates less than 1.0 correspond to out-of-the-money swaptions, and StrikeRates greater than 1.0 correspond to in-the-money swaptions. • **ForwardStrike2**: The strike of the option is derived in an additive sense as follows: $\text{Strike} = \text{EquilibriumForwardSwapRate}(t) + \text{StrikeRate}$ where EquilibriumForwardSwapRate(*t*) is the fixed rate that is required to price the forward starting swap at zero, based on the yield curve at this time step. This means that for a forward at-the-money swaption you enter a StrikeRate of 0.0. Negative values of StrikeRate correspond to out-of-the-money swaptions, whereas positive values of StrikeRate correspond to in-the-money swaptions. • **AbsoluteStrike**: The strike of the option is just the input StrikeRate. *For example*, to set the strike at a swap rate of 5%, enter a value of 0.05 for StrikeRate. Since the yield curve generally changes at each time step, there is no way to ascertain the moneyness definitively of these swaptions. The calculations proceed as follows. First the swaption is priced (semi-)analytically based on the prevailing yield curve, and then calculation of the implied volatility is attempted. There are a few cases when this fails: • When the analytical swaption price is outside of the theoretical limits for option price, the implied volatility output is set to zero. This might come about because of tiny numerical inaccuracies in the numerical integration, most commonly when the option price is extremely small as might be

Name	Description
	the case when the option is far out-of-the-money or deep in-the-money. Alternatively it might arise because of negative interest rates leading to a negative underlying annuity price or a discount factor greater than 1.0. • When the swaption is sufficiently far out-of-the-money or sufficiently deep in-the-money such that the option price sensitivity to volatility (that is, the Greek known as Vega) is zero, the implied volatility output is set to zero. In these cases, there are a wide range of volatilities that reproduce the swaption price to the limits of machine precision, and hence any solution obtained from the calculations would not be unique.

NominalYieldCurve [AnnualLMM, SemiAnnualLMM, MonthlyLMM]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A Heath, Jarrow, and Morton (HJM) model with LIBOR forward rates (simply compounded rates) and proportional volatilities. This implementation is a two-factor version and features deterministic volatility scaling factors for each initial rate, and a change of probability measure via the numéraire bond maturity term. For more information, see the MaturityOfNumeraireBond parameter of Simulation.

Note The type of the model (Annual, SemiAnnual, or Monthly) must match the simulation time step.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	The factor 1 volatility. The name 'ShortRate' is misleading for this model and only used to be consistent with other yield curve models. This name means that the model can use the same correlation matrix entries as other interest rate models.
MeanReversionLevel	The factor 2 volatility. The name 'MeanReversionLevel' is misleading for this model and only used to be consistent with other yield curve models. This name means that the model can use the same correlation matrix entries as other interest rate models.

Input variables

Name	Description
StartRates	The initial term structure of maturities of the simple forward rates that are uniformly increasing by a constant tenor. The tenor of the simple forward rates should match the simulation time step. Initial forward rates must be nonnegative.
Gamma	Nominal interest rate "market price of risk". This parameter is only used in simulations run with the UseRiskNeutralValuation parameter set to False, which corresponds to real-world simulation. When the UseRiskNeutralValuation parameter is set to True, the parameter is inactive, being effectively set to zero.

Name	Description
BoundingMethod	The bounding method for forward rates. Use this parameter to mitigate forward rate explosions (extreme upper rate percentiles which can be observed for long simulation horizons) by using a cap level, by freezing forward rate paths that exceed a threshold, or both. Possible values: • **None**—The simulation evolves forward rates without applying a bounding method. • **Cap**—The simulation applies a cap on forward rates. If any forward rate exceeds the **ForwardRateCap** value, then it is reduced to the level of the cap. • **Freeze**—The simulation applies path freezing when the threshold is exceeded. If, for any given trial and time step, any forward rate exceeds the **PathFreezeThreshold** value, then for that trial and from the next time step onwards the forward rates evolve deterministically. • **Cap and Freeze**—The simulation applies the **Cap** and **Freeze** methods simultaneously.
ForwardRateCap	The level of the cap that the simulation applies to forward rates when you set the **BoundingMethod** to **Cap** or **Cap and Freeze**. The cap is expressed as an absolute simple forward rate.
PathFreezeThreshold	The threshold that triggers a path freeze in the simulation, used when you select **Freeze** or **Cap and Freeze** as the **BoundingMethod**. The threshold is expressed as an absolute simple forward rate.
VolatilityScalingFactors	Scaling factors for the volatility. The number of elements of this parameter set should match the length of the volatility factors and the length of start rates.
LMM Modelled Years	This parameter provides a simple way to avoid unnecessary calculations in the latter part of the yield curve that might not be required anyway, and hence can be used to speed up the simulation. The parameter sets defining the yield curve model (start rates, volatility factors, and so on) are effectively truncated to a length (in years) of LMM Modelled Years. *For example*, if 20-year bond prices are to be simulated over a total of 40 years then LMM Modelled Years can be set to 60 without affecting calculated values. When calculations involve pricing of bonds with term longer than LMM Modelled Years, a constant forward rate extrapolation is used. A restriction is that LMM Modelled Years must be at least as long as the total simulation horizon (as defined by the simulation time steps).
InitialIndexValue	The base value for index outputs.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate.Value}(t-\Delta t)\Delta t)$ where CashTotalReturnIndex(0) = InitialIndexValue.
CashTotalReturn	The total return of cash over the time step. $\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)} - 1$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $\mathrm{AnnualisedCashTotalReturn}(t) = (1+\mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$

Name	Description
	Note Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The continuously compounded nominal interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\mathrm{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the length of the next simulation time step $[t, t + \Delta t]$.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $$\mathrm{AnnualisedShortRate}(t) = \exp(\mathrm{ShortRate.Value}(t)) - 1$$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \left(\frac{1}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}\right)^{\frac{1}{\mathrm{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \mathrm{CompoundingFrequency}, t) = \mathrm{CompoundingFrequency} \times \left\{(1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))^{\frac{1}{\mathrm{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \infty, t) = \ln(1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))$$
ForwardRate [CreditClass, Maturity, Seniority]	The annualized forward rate applying over the tenor Δt equal to the length of the next simulation time step $[t, t + \Delta t]$, calculated using the formula: $$\mathrm{ForwardRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \frac{1}{\Delta t}\left(\frac{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity} + \Delta t, \mathrm{Seniority}, t)} - 1\right)$$
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\mathrm{AnnuityPrice}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \sum_{\tau=1}^{\mathrm{Maturity}} \mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority}, t)$$

Name	Description
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, \mathrm{CreditClass}, \tau, \mathrm{Seniority}) = f\frac{1-\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})}{\sum_{n=1}^{f\times\tau}\mathrm{ZCBP}\left(\mathrm{CreditClass}, \frac{n}{f}, \mathrm{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td>Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel]</td><td>Outputs time-zero swaption prices and implied volatilities with swaption maturities corresponding to each time step. The underlying swap has an annual payment frequency. Fill the following fields:

SwaptionType—Payer or Receiver.
StrikeType—This parameter, together with the StrikeRate, defines the strike of the option. Possible values:

ForwardStrike1—The software calculates the swaption strike as the corresponding forward swap rate multiplied by the input StrikeRate.
ForwardStrike2—The software calculates the swaption strike as the corresponding forward swap rate plus the input StrikeRate.
AbsoluteStrike—The swaption strike equals the input StrikeRate.

StrikeRate—This parameter, together with the StrikeType determines the swaption strike rate.
SwapTenor—The tenor of the underlying swap.
ImpliedVolatilityType—The basis by which the implied volatility is reported. Possible values:

Lognormal—The software quotes the volatility on a "displaced log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement, then a standard log-normal volatility is reported.
Normal—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate.

Displacement—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal.
SignificanceLevel—The significance level used for reporting the confidence interval for estimated swaption implied volatility. The preset value, 0.05, corresponds to a 95% confidence interval.
</td></tr>
<tr><td>Local Currency Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel]</td><td>A local currency version of the Swaption Test (described above) which uses the local economy's nominal yield curve to calculate prices (instead of the base economy of the simulation).
The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.</td></tr>
<tr><td>Zero Coupon Bond Martingale Test</td><td>Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.</td></tr>
<tr><td>Local Currency Zero Coupon Bond Martingale Test</td><td>Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation).
The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.</td></tr>
</table>

VolatilityFactor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The factors represent a principal component of the forward rate yield curve covariance matrix.

Input variables

Name	Description
FactorVolatility	A parameter set with volatilities for this factor. The number of entries in the parameter set must match the number of start rates for the LMM.

NominalYieldCurve [AnnualLMMPlus, SemiAnnualLMMPlus, MonthlyLMMPlus]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A Heath, Jarrow, and Morton (HJM) model with LIBOR forward rates (simply compounded rates). This implementation is a two-factor version, and features a stochastic volatility scaling factor, constant displacement, change of probability measure via the numéraire bond maturity term, and a Brownian bridge discretization applied to the volatility (variance) process.

For more information about the change of probability measure, see the MaturityOfNumeraireBond parameter of Simulation.

Note The type of the model (Annual, SemiAnnual, or Monthly) must match the simulation time step.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
ShortRate	The factor 1 volatility. The name 'ShortRate' is misleading for this model and only used to be consistent with other yield curve models. This name means that the model can use the same correlation matrix entries as other interest rate models.
MeanReversionLevel	The factor 2 volatility. The name 'MeanReversionLevel' is misleading for this model and only used to be consistent with other yield curve models. This name means that the model can use the same correlation matrix entries as other interest rate models.
Volatility	Volatility is a stochastic variable which is described by the square root of the Cox-Ingersoll-Ross (CIR) process. The CIR process models the instantaneous variance and is correlated with the interest rate factor shocks of the forward rates using the Correlation parameter Embedded image.

Input variables

Name	Description	Conditions
StartRates	The initial term structure of maturities of the simple forward rates that are uniformly increasing by a constant tenor. The tenor of the simple forward rates should match the simulation time step. Initial forward rates must be greater than or equal to the negative equivalent of the value entered for the **ForwardRateDisplacement**. A restriction is that modeled years (the minimum of the LMM Modelled Years and the horizon of the StartRates) must be at least as long as the total simulation horizon (as defined by the simulation time steps).	
Gamma	Nominal interest rate "market price of risk".	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**. If **UseRiskNeutralValuation** is **True**, then **Gamma** is 0.
BoundingMethod	The bounding method for forward rates. Use this parameter to mitigate forward rate explosions (extreme upper rate percentiles which can be observed for long simulation horizons) by using cap and floor levels, by freezing forward rate paths that are greater than or less than set thresholds, or both. Possible values: • **None**—The simulation evolves forward rates without applying a bounding method. • **Cap/Floor**—The simulation applies a cap and floor on forward rates. If any forward rate exceeds the **ForwardRateCap** value, then it is reduced to the level of the cap. If any forward rate is less than the **ForwardRateFloor** value, then it is increased to the level of the floor. • **Freeze**—The simulation applies path freezing when the threshold is exceeded. If, for any given trial and time step, any forward rate is greater than the **UpperPathFreezeThreshold** value or less than the **LowerPathFreezeThreshold** value, then for that trial and from the next time step onwards the forward rates evolve deterministically. • **Cap/Floor and Freeze**—The simulation applies the **Cap/Floor** and **Freeze** methods simultaneously.	
ForwardRateCap	The maximum allowed forward rate to mitigate extreme upper rate percentile (exploding rates) for long simulation horizons and problematic scenarios. The simulation applies this cap to forward rates when you set the **BoundingMethod** to **Cap/Floor** or **Cap/Floor and Freeze**. The cap is expressed as an absolute simple forward rate.	Enabled only if **BoundingMethod** is **Cap/Floor** or **Cap/Floor and Freeze**.
ForwardRateFloor	The smallest allowed forward rate to mitigate the size and or frequency of negative rates. The simulation applies this floor to forward rates when you set the **BoundingMethod** to **Cap/Floor** or **Cap/Floor and Freeze**. The floor is expressed as an absolute simple forward rate.	Enabled only if **BoundingMethod** is **Cap/Floor** or **Cap/Floor and Freeze**.
UpperPathFreezeThreshold	The upper threshold that triggers a path freeze in the simulation, used when you select **Freeze** or **Cap/Floor and Freeze** as the **BoundingMethod**. The threshold is expressed as an absolute simple forward rate.	Enabled only if BoundingMethod is **Freeze** or **Cap/Floor and Freeze**.
LowerPathFreezeThreshold	The lower threshold that triggers a path freeze in the simulation, used when you select **Freeze** or **Cap/Floor and Freeze** as the **BoundingMethod**. The threshold is expressed as an absolute simple forward rate.	Enabled only if BoundingMethod is **Freeze** or **Cap/Floor and Freeze**.
LMM Modelled Years	This parameter provides a simple way to avoid unnecessary calculations in the latter part of the yield curve that might not be required anyway, and hence can be used to speed up the simulation.	

Name	Description	Conditions
	The parameter sets defining the yield curve model (start rates, volatility factors, and so on) are effectively truncated to a length (in years) of LMM Modelled Years. *For example*, if 20-year bond prices are to be simulated over a total of 40 years then LMM Modelled Years can be set to 60 without affecting calculated values. When calculations involve pricing of bonds with term longer than LMM Modelled Years, a constant forward rate extrapolation is used. A restriction is that modeled years (the minimum of the LMM Modelled Years and the horizon of the StartRates) must be at least as long as the total simulation horizon (as defined by the simulation time steps).	
ForwardRateDisplacement	This parameter controls the size of the deviation of the model from the *geometric* proportional volatility. The displacement must lie in the interval $[0, 1/\tau]$, where τ denotes the LIBOR tenor of the model. *For example*, if you use the MonthlyLMMPlus model, then the tenor of the simple forward rate is equal to 1/12, and you cannot enter a displacement greater than 12 (1200%). A displacement of 0 corresponds to the geometric (log-normal) setup of this model, whereas a displacement of 12 corresponds to a Gaussian short-rate type model.	
NumberOfSubdivisions	The parameter of the Brownian bridge algorithm which controls the sampling frequency (with respect to the simulation time step) of the stochastic differential equations governing this model.	
DriftCalculationsPerTimestep	Controls the number of times that the drift of the forward rate is calculated in a given time step. This parameter has significance when the **NumberOfSubdivisions** parameter is greater than 1.	
InitialIndexValue	The base value for index outputs.	

Outputs

Name	Description
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$
CashTotalReturn	The total return of cash over the time step. $\text{CashTotalReturn}(t) = \frac{\text{CashTotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t - \Delta t)} - 1$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.

Name	Description
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t) = (1 + \text{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
CashTotalReturnIndex	The total return index of cash. $$\text{CashTotalReturnIndex}(t) = \text{CashTotalReturnIndex}(t - \Delta t)\exp(\text{ShortRate}(t - \Delta t)\Delta t)$$ where CashTotalReturnIndex(0) = InitialIndexValue.
ForwardAnnuityPrice [Maturity, AnnuityTenor, AnnuityPaymentFrequency]	The price of a forward-starting annuity. Fill the following fields: • **Maturity**—The time until the annuity starts. • **AnnuityTenor**—The length of time over which annuity payments are made. • **AnnuityPaymentFrequency**—The payment frequency of the annuity.
ForwardRate [CreditClass, Maturity, Seniority]	The annualized forward rate applying over the tenor Δt equal to the length of the next simulation time step $[t, t + \Delta t]$, calculated using the formula: $$\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{1}{\Delta t}\left(\frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + \Delta t, \text{Seniority}, t)} - 1\right)$$
ForwardSwapRate [Maturity, SwapTenor, SwapPaymentFrequency]	The forward swap rate. Fill the following fields: • **Maturity**—The time until the underlying swap starts. • **SwapTenor**—The tenor of the underlying swap. • **SwapPaymentFrequency**—The payment frequency of the underlying swap.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\text{ParYield}(f, \text{CreditClass}, \tau, \text{Seniority}) = f\frac{1 - \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})}{\sum_{n=1}^{f\times\tau} \text{ZCBP}\left(\text{CreditClass}, \frac{n}{f}, \text{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.
ShortRate	The continuously compounded nominal interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the length of the next simulation time step $[t, t + \Delta t]$.

Name	Description
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\text{SpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass},\text{Maturity},\text{Seniority},t)}\right)^{\frac{1}{\text{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\text{CustomSpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},\text{CompoundingFrequency},t) = \text{CompoundingFrequency} \times \left\{(1+\text{SpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\text{CustomSpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},\infty,t) = \ln(1+\text{SpotRate}(\text{CreditClass},\text{Maturity},\text{Seniority},t))$$
SwaptionImpliedVolatility [SwaptionType, StrikeType, StrikeRate, Maturity, SwapTenor, ImpliedVolatilityType, Displacement]	The implied volatility of a swaption with the specified features. The underlying swap has an annual payment frequency. Fill the following fields: • **SwaptionType**—Payer or Receiver. • **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. Possible values: ◦ **ForwardStrike1**—The software calculates the swaption strike as the corresponding ForwardSwapRate multiplied by the input StrikeRate. ◦ **ForwardStrike2**—The software calculates the swaption strike as the corresponding ForwardSwapRate plus the input StrikeRate. ◦ **AbsoluteStrike**—The swaption strike equals the input StrikeRate. • **StrikeRate**—This parameter, together with the StrikeType determines the swaption strike rate. • **Maturity**—The maturity of the swaption, which must be an integer. • **SwapTenor**—The tenor of the underlying swap. • **ImpliedVolatilityType**—The basis by which the swaption implied volatility is reported. Possible values: ◦ **Lognormal**—The software quotes the volatility on a "displaced Log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement the software reports a standard log-normal volatility. ◦ **Normal**—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate. • **Displacement**—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal.
SwaptionPrice [SwaptionType, StrikeType, StrikeRate, Maturity, SwapTenor]	The price of a swaption with the specified features. The underlying swap has an annual payment frequency. Fill the following fields: • **SwaptionType**—**Payer** or **Receiver**. • **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. Possible values: ◦ **ForwardStrike1** —The software calculates the swaption strike as the corresponding ForwardSwapRate multiplied by the input StrikeRate. ◦ **ForwardStrike2**—The software calculates the swaption strike as the corresponding ForwardSwapRate plus the input StrikeRate. ◦ **AbsoluteStrike**—The swaption strike equals the input StrikeRate.

Name	Description
	• **StrikeRate**—This parameter, together with the StrikeType determines the swaption strike rate. • **Maturity**—The maturity of the swaption, which must be an integer. • **SwapTenor**—The tenor of the underlying swap.
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.

Analysis tests

Name	Description
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Forward Swap Rate Test [SwapTenor, Frequency]	Outputs time-zero forward swap rates for underlying swaps starting at each time step. Fill the following fields: • **SwapTenor**—The tenor of the underlying swap. • **Frequency**—The payment frequency of the underlying swap.
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Swaption Implied Volatility Test Abs [SwaptionType, AbsStrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The strike of the contract is calculated as the value of the **AbsStrikeRate** (absolute strike rate).

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td>Swaption Implied Volatility Test Diff [SwaptionType, AbsStrRateDiff, SwapTenor, IncludeAnalyticVol]</td><td>Outputs swaption prices and implied volatilities for a given SwaptionType, Tenor, and strike. The strike of the contract is calculated as forward swap rate of the contract, plus the AbsStrRateDiff (absolute strike rate difference).

When you select this test, you can choose whether to output analytic swaption implied volatilities at time step 0.

Note If you select to include analytic volatilities, this test gives a value for integer maturities. For non-integer maturities, analytic implied volatilities are NaN.</td></tr>
<tr><td>Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]</td><td>Outputs time-zero swaption prices and implied volatilities with swaption maturities corresponding to each time step. The underlying swap has an annual payment frequency. Fill the following fields:

SwaptionType—Payer or Receiver.
StrikeType—This parameter, together with the StrikeRate, defines the strike of the option. Possible values:

ForwardStrike1 —The software calculates the swaption strike as the corresponding forward swap rate multiplied by the input StrikeRate.
ForwardStrike2—The software calculates the swaption strike as the corresponding forward swap rate plus the input StrikeRate.
AbsoluteStrike—The swaption strike equals the input StrikeRate.

StrikeRate—This parameter, together with the StrikeType determines the swaption strike rate.
SwapTenor—The tenor of the underlying swap.
ImpliedVolatilityType—The basis by which the implied volatility is reported. Possible values:

Lognormal —The software quotes the volatility on a "displaced log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement, then a standard log-normal volatility is reported.
Normal—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate.

Displacement—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal.
SignificanceLevel—The significance level used for reporting the confidence interval for estimated swaption implied volatility. The preset value, 0.05, corresponds to a 95% confidence interval.
IncludeAnalyticVol—To include analytical (model) volatility and price, select True.

Note This test gives a value for integer maturities. For non-integer maturities, analytic implied volatilities are NaN.</td></tr>
<tr><td>Local Currency Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]</td><td>A local currency version of the Swaption Test (described above) which uses the local economy's nominal yield curve to calculate prices (instead of the base economy of the simulation).

The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.</td></tr>
<tr><td>Zero Coupon Bond Martingale Test</td><td>Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.</td></tr>
<tr><td>Local Currency Zero Coupon Bond Martingale Test</td><td>Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation).

The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.</td></tr>
</table>

VolatilityFactor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The factors represent a principal component of the forward rate yield curve covariance matrix.

Input variables

Name	Description
FactorVolatility	A parameter set with volatilities for this factor. The number of entries in the parameter set must match the number of start rates for the LMMPlus.

Volatility

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Volatility is a stochastic variable which is described by the square root of the Cox-Ingersoll-Ross (CIR) process. The CIR process models the instantaneous variance and is correlated with the interest rate factor shocks of the forward rates using the Correlation parameter ρ. For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Input variables

Name	Description	Conditions
MeanReversionRate	The mean reversion rate of the underlying stochastic variance process.	
Volatility	The volatility of the underlying stochastic variance process.	
MeanReversionLevel	The mean reversion level of the underlying stochastic variance process.	
RiskNeutralMeanReversionRate	The risk neutral rate of mean reversion of the underlying stochastic variance process.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMeanReversionLevel	The risk neutral mean reversion level of the underlying stochastic variance process.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
InitialValue	The initial value of the underlying stochastic variance process.	
Correlation	The correlation between the combined factor shocks of the forward rate process and the underlying stochastic variance process.	

Outputs

Name	Description
Volatility	The square root of the value of the stochastic variance process.
SwaptionImpliedVolatility [StrikeRate, StrikeType, Maturity, Tenor]	This output calculates the implied volatility (using Black 76 model assumptions) of a swaption with the specified features and an annual swap frequency. Enter the following parameters: • **StrikeRate**—This parameter, together with the StrikeType defines the strike of the option. See below for details. • **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. • **Maturity**—The maturity of the option in years. • **Tenor**—The tenor (total term) of the underlying swap contract. The strike of the option is determined by the StrikeRate, StrikeType, and the prevailing yield curve via the equilibrium forward swap rate. The StrikeType governs how this is determined as follows: • **ForwardStrike1**: The strike of the option is derived in a multiplicative sense as follows: $\text{Strike} = \text{EquilibriumForwardSwapRate}(t) \times \text{StrikeRate}$ where EquilibriumForwardSwapRate(*t*) is the fixed rate that is required to price the forward starting swap at zero, based on the yield curve at this time step. This means that for a forward at-the-money swaption you enter a StrikeRate of 1.0. StrikeRates less than 1.0 correspond to out-of-the-money swaptions, and StrikeRates greater than 1.0 correspond to in-the-money swaptions. • **ForwardStrike2**: The strike of the option is derived in an additive sense as follows: $\text{Strike} = \text{EquilibriumForwardSwapRate}(t) + \text{StrikeRate}$ where EquilibriumForwardSwapRate(*t*) is the fixed rate that is required to price the forward starting swap at zero, based on the yield curve at this time step. This means that for a forward at-the-money swaption you enter a StrikeRate of 0.0. Negative values of StrikeRate correspond to out-of-the-money swaptions, whereas positive values of StrikeRate correspond to in-the-money swaptions. • **AbsoluteStrike**: The strike of the option is just the input StrikeRate. *For example*, to set the strike at a swap rate of 5%, enter a value of 0.05 for StrikeRate. Since the yield curve generally changes at each time step, there is no way to ascertain the moneyness definitively of these swaptions. The calculations proceed as follows. First the swaption is priced (semi-)analytically based on the prevailing yield curve, and then calculation of the implied volatility is attempted. There are a few cases when this fails: • When the analytical swaption price is outside of the theoretical limits for option price, the implied volatility output is set to zero. This might come about because of tiny numerical inaccuracies in the numerical integration, most commonly when the option price is extremely small as might be the case when the option is far out-of-the-money or deep in-the-money. Alternatively it might arise because of negative interest rates leading to a negative underlying annuity price or a discount factor greater than 1.0. • When the swaption is sufficiently far out-of-the-money or sufficiently deep in-the-money such that the option price sensitivity to volatility (that is, the Greek known as Vega) is zero, the implied volatility output is set to zero. In these cases, there are a wide range of volatilities that reproduce the swaption price to the limits of machine precision, and hence any solution obtained from the calculations would not be unique.

NominalYieldCurve [AnnualLMMPlusMFV, SemiAnnualLMMPlusMFV, MonthlyLMMPlusMFV]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A Heath, Jarrow, and Morton (HJM) model with LIBOR forward rates (simply compounded rates). This implementation has a variable number of factors and features a stochastic volatility scaling factor, constant displacement, change of probability measure via the numeraire bond maturity term (for more information, see the MaturityOfNumeraireBond parameter of Simulation), a Brownian bridge discretization applied to the volatility (variance) process.

Note The type of the model (Annual, SemiAnnual, or Monthly) must match the simulation time step.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
Volatility [CIRVolatilityMuMFV]	Volatility is a stochastic variable which is described by the square root of the Cox-Ingersoll-Ross (CIR) process. The CIR process models the instantaneous variance and is correlated with the interest rate factor shocks of the forward rates using the correlation parameter, ρ.
Factor1	The factor 1 volatility.
Factor2	The factor 2 volatility.

Addable submodels

Name	Description
Factor [VolatilityFactorMu]	An extra volatility factor. Any number of factors can be added to the model, and these factors are named automatically so as to maintain contiguous factor labeling for calibration purposes. **Note** Only the most recently added factor (highest numbered factor) can be deleted, subject to a minimum of two factors. Again, this limitation is to maintain contiguous labeling.

Input variables

Name	Description	Conditions
StartRates	The initial term structure of maturities of the simple forward rates that are uniformly increasing by a constant tenor. The tenor of the simple forward rates should match the simulation time step. Initial forward rates must be greater or equal to minus ForwardRateDisplacement parameter.	
Gamma	Nominal interest rate "market price of risk".	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**. If **UseRiskNeutralValuation** is **True**, then **Gamma** is 0.
BoundingMethod	The bounding method for forward rates. Use this parameter to mitigate forward rate explosions (extreme upper rate percentiles which can be observed for long simulation horizons) by using cap and floor levels, by	

Name	Description	Conditions
	freezing forward rate paths that are greater than or less than set thresholds, or both. Possible values: • **None**—The simulation evolves forward rates without applying a bounding method. • **Cap/Floor**—The simulation applies a cap and floor on forward rates. If any forward rate exceeds the **ForwardRateCap** value, then it is reduced to the level of the cap. If any forward rate is less than the **ForwardRateFloor** value, then it is increased to the level of the floor. • **Freeze**—The simulation applies path freezing when the threshold is exceeded. If, for any given trial and time step, any forward rate is greater than the **UpperPathFreezeThreshold** value or less than the **LowerPathFreezeThreshold** value, then for that trial and from the next time step onwards the forward rates evolve deterministically. • **Cap/Floor and Freeze**—The simulation applies the **Cap/Floor** and **Freeze** methods simultaneously.	
ForwardRateCap	The maximum allowed forward rate to mitigate extreme upper rate percentile (exploding rates) for long simulation horizons and problematic scenarios.The simulation applies this cap to forward rates when you set the **BoundingMethod** to **Cap/Floor** or **Cap/Floor and Freeze**. The cap is expressed as an absolute simple forward rate.	Enabled only if **BoundingMethod** is **Cap/Floor** or **Cap/Floor and Freeze**.
ForwardRateFloor	The smallest allowed forward rate to mitigate the size and or frequency of negative rates. The simulation applies this floor to forward rates when you set the **BoundingMethod** to **Cap/Floor** or **Cap/Floor and Freeze**. The floor is expressed as an absolute simple forward rate.	Enabled only if **BoundingMethod** is **Cap/Floor** or **Cap/Floor and Freeze**.
UpperPathFreezeThreshold	The upper threshold that triggers a path freeze in the simulation, used when you select **Freeze** or **Cap/Floor and Freeze** as the **BoundingMethod**. The threshold is expressed as an absolute simple forward rate.	Enabled only if BoundingMethod is **Freeze** or **Cap/Floor and Freeze**.
LowerPathFreezeThreshold	The lower threshold that triggers a path freeze in the simulation, used when you select **Freeze** or **Cap/Floor and Freeze** as the **BoundingMethod**. The threshold is expressed as an absolute simple forward rate.	Enabled only if BoundingMethod is **Freeze** or **Cap/Floor and Freeze**.
LMM Modelled Years	This parameter provides a simple way to avoid unnecessary calculations in the latter part of the yield curve that might not be required anyway, and hence can be used to speed up the simulation. The parameter sets defining the yield curve model (start rates, volatility factors, and so on) are effectively truncated to a length (in years) of LMM Modelled Years. *For example*, if 20-year bond prices are to be simulated over a total of 40 years then LMM Modelled Years can be set to 60 without affecting calculated values. When calculations involve pricing of bonds with term longer than LMM Modelled Years, a constant forward rate extrapolation is used. A restriction is that LMM Modelled Years must be at least as long as the total simulation horizon (as defined by the simulation time steps).	
ForwardRateDisplacement	This parameter controls the size of the deviation of the model from the *geometric* proportional volatility. The displacement must lie in the interval $[0, 1/\tau]$, where τ denotes the LIBOR tenor of the model. *For example*, if you use the MonthlyLMMPlus model, then the tenor of the simple forward rate is equal to 1/12, and you cannot enter a displacement greater than 12 (1200%). A displacement of 0 corresponds to the geometric (log-normal) setup of this model, whereas a displacement of 12 corresponds to a Gaussian short-rate type model.	

Name	Description	Conditions
NumberOfSubdivisions	The parameter of the Brownian bridge algorithm which controls the sampling frequency (with respect to the simulation time step) of the stochastic differential equations governing this model.	
DriftCalculationsPerTimestep	Controls the number of times that the drift of the forward rate is calculated in a given time step. This parameter has significance when the **NumberOfSubdivisions** parameter is greater than 1.	
InitialIndexValue	The base value for index outputs.	

Outputs

Name	Description
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $$\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$$
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$$
CashTotalReturn	The total return of cash over the time step. $$\text{CashTotalReturn}(t) = \frac{\text{CashTotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t - \Delta t)} - 1$$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t) = (1 + \text{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
CashTotalReturnIndex	The total return index of cash. $$\text{CashTotalReturnIndex}(t) = \text{CashTotalReturnIndex}(t - \Delta t)\exp(\text{ShortRate}(t - \Delta t)\Delta t)$$ where CashTotalReturnIndex(0) = InitialIndexValue.
ForwardAnnuityPrice [Maturity, AnnuityTenor, AnnuityPaymentFrequency]	The price of a forward-starting annuity. Fill the following fields: • **Maturity**—The time until the annuity starts. • **AnnuityTenor**—The length of time over which annuity payments are made. • **AnnuityPaymentFrequency**—The payment frequency of the annuity.

Name	Description
ForwardRate [CreditClass, Maturity, Seniority]	The annualized forward rate applying over the tenor Δt equal to the length of the next simulation time step $[t, t+\Delta t]$, calculated using the formula: $$\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{1}{\Delta t}\left(\frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}+\Delta t, \text{Seniority}, t)} - 1\right)$$
ForwardSwapRate [Maturity, SwapTenor, SwapPaymentFrequency]	The forward swap rate. Fill the following fields: • **Maturity**—The time until the underlying swap starts. • **SwapTenor**—The tenor of the underlying swap. • **SwapPaymentFrequency**—The payment frequency of the underlying swap.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\text{ParYield}(f, \text{CreditClass}, \tau, \text{Seniority}) = f\frac{1-\text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})}{\sum_{n=1}^{f\times\tau}\text{ZCBP}\left(\text{CreditClass}, \frac{n}{f}, \text{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.
ShortRate	The continuously compounded nominal interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the length of the next simulation time step $[t, t+\Delta t]$.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1+\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1+\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$$
SwaptionImpliedVolatility [SwaptionType, StrikeType, StrikeRate, Maturity, SwapTenor, ImpliedVolatilityType, Displacement]	The implied volatility of a swaption with the specified features. The underlying swap has an annual payment frequency. Fill the following fields: • **SwaptionType**—Payer or Receiver.

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td></td><td>

StrikeType—This parameter, together with the StrikeRate, defines the strike of the option. Possible values:

ForwardStrike1—The software calculates the swaption strike as the corresponding ForwardSwapRate multiplied by the input StrikeRate.
ForwardStrike2—The software calculates the swaption strike as the corresponding ForwardSwapRate plus the input StrikeRate.
AbsoluteStrike—The swaption strike equals the input StrikeRate.

StrikeRate—This parameter, together with the StrikeType determines the swaption strike rate.
Maturity—The maturity of the swaption, which must be an integer.
SwapTenor—The tenor of the underlying swap.
ImpliedVolatilityType—The basis by which the swaption implied volatility is reported. Possible values:

Lognormal—The software quotes the volatility on a "displaced Log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement the software reports a standard log-normal volatility.
Normal—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate.

Displacement—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal.

</td></tr>
<tr><td>SwaptionPrice [SwaptionType, StrikeType, StrikeRate, Maturity, SwapTenor]</td><td>
The price of a swaption with the specified features. The underlying swap has an annual payment frequency. Fill the following fields:

SwaptionType—Payer or Receiver.
StrikeType—This parameter, together with the StrikeRate, defines the strike of the option. Possible values:

ForwardStrike1 —The software calculates the swaption strike as the corresponding ForwardSwapRate multiplied by the input StrikeRate.
ForwardStrike2—The software calculates the swaption strike as the corresponding ForwardSwapRate plus the input StrikeRate.
AbsoluteStrike—The swaption strike equals the input StrikeRate.

StrikeRate—This parameter, together with the StrikeType determines the swaption strike rate.
Maturity—The maturity of the swaption, which must be an integer.
SwapTenor—The tenor of the underlying swap.

</td></tr>
<tr><td>ZCBP [CreditClass, Maturity, Seniority]</td><td>The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.</td></tr>
</table>

Analysis tests

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td>Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]</td><td>
Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields.
After selecting the test, enter the following values for each bond:

Name—A name for the bond.
CreditClass—The credit class for the bond issuer.
Seniority—The seniority of the bond.
Term—The term of the bond.

</td></tr>
</table>

Name	Description
	• **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Forward Swap Rate Test [SwapTenor, Frequency]	Outputs time-zero forward swap rates for underlying swaps starting at each time step. Fill the following fields: • **SwapTenor**—The tenor of the underlying swap. • **Frequency**—The payment frequency of the underlying swap.
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Swaption Implied Volatility Test Abs [SwaptionType, AbsStrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The strike of the contract is calculated as the value of the **AbsStrikeRate** (absolute strike rate).
Swaption Implied Volatility Test Diff [SwaptionType, AbsStrRateDiff, SwapTenor, IncludeAnalyticVol]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The strike of the contract is calculated as forward swap rate of the contract, plus the **AbsStrRateDiff** (absolute strike rate difference). When you select this test, you can choose whether to output analytic swaption implied volatilities at time step 0. **Note** If you select to include analytic volatilities, this test gives a value for integer maturities. For non-integer maturities, analytic implied volatilities are NaN.

Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]	Outputs time-zero swaption prices and implied volatilities with swaption maturities corresponding to each time step. The underlying swap has an annual payment frequency. Fill the following fields:
	• **SwaptionType**—Payer or Receiver.
	• **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. Possible values:
	  ◦ **ForwardStrike1** —The software calculates the swaption strike as the corresponding forward swap rate multiplied by the input StrikeRate.
	  ◦ **ForwardStrike2**—The software calculates the swaption strike as the corresponding forward swap rate plus the input StrikeRate.
	  ◦ **AbsoluteStrike**—The swaption strike equals the input StrikeRate.

Name	Description

	• **StrikeRate**—This parameter, together with the StrikeType determines the swaption strike rate.
	• **SwapTenor**—The tenor of the underlying swap.
	• **ImpliedVolatilityType**—The basis by which the implied volatility is reported. Possible values:
	  ◦ **Lognormal** —The software quotes the volatility on a "displaced log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement, then a standard log-normal volatility is reported.
	  ◦ **Normal**—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate.
	• **Displacement**—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal.
	• **SignificanceLevel**—The significance level used for reporting the confidence interval for estimated swaption implied volatility. The preset value, 0.05, corresponds to a 95% confidence interval.
	• **IncludeAnalyticVol**—To include analytical (model) volatility and price, select **True**.
	Note This test gives a value for integer maturities. For non-integer maturities, analytic implied volatilities are NaN.

Local Currency Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]	A local currency version of the Swaption Test (described above) which uses the local economy's nominal yield curve to calculate prices (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Zero Coupon Bond Martingale Test	Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Local Currency Zero Coupon Bond Martingale Test	Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.

Volatility [CIRVolatilityMuMFV]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Volatility is a stochastic variable which is described by the square root of the Cox-Ingersoll-Ross (CIR) process. The CIR process models the instantaneous variance and is correlated with the interest rate factor shocks of the forward rates using the Correlation parameter ρ. For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Input variables

Name	Description	Condition
MeanReversionRate	The mean reversion rate of the underlying stochastic variance process	
Volatility	The volatility of the underlying stochastic variance process	
MeanReversionLevel	The mean reversion level of the underlying stochastic variance process	
InitialValue	The initial value of the underlying stochastic variance process	
Correlation	The correlation between the combined factor shocks of the forward rate process and the underlying stochastic variance process.	
RiskNeutralMeanReversionLevel	The risk neutral mean reversion level of the underlying stochastic variance process.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMeanReversionRate	The risk neutral rate of mean reversion of the underlying stochastic variance process.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Volatility	The square root of the value of the stochastic variance process.
SwaptionImpliedVolatility [StrikeRate, StrikeType, Maturity, Tenor]	This output calculates the implied volatility (using Black 76 model assumptions) of a swaption with the specified features and an annual swap frequency. Enter the following parameters: • **StrikeRate**—This parameter, together with the StrikeType defines the strike of the option. See below for details. • **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. • **Maturity**—The maturity of the option in years. • **Tenor**—The tenor (total term) of the underlying swap contract. The strike of the option is determined by the StrikeRate, StrikeType, and the prevailing yield curve via the equilibrium forward swap rate. The StrikeType governs how this is determined as follows: • **ForwardStrike1**: The strike of the option is derived in a multiplicative sense as follows: $\text{Strike} = \text{EquilibriumForwardSwapRate}(t) \times \text{StrikeRate}$ where EquilibriumForwardSwapRate(*t*) is the fixed rate that is required to price the forward starting swap at zero, based on the yield curve at this time step. This means that for a forward at-the-money swaption you enter a StrikeRate of 1.0. StrikeRates less than 1.0 correspond to out-of-the-money swaptions, and StrikeRates greater than 1.0 correspond to in-the-money swaptions. • **ForwardStrike2**: The strike of the option is derived in an additive sense as follows: $\text{Strike} = \text{EquilibriumForwardSwapRate}(t) + \text{StrikeRate}$ where EquilibriumForwardSwapRate(*t*) is the fixed rate that is required to price the forward starting swap at zero, based on the yield curve at this time step. This means that for a forward at-the-money swaption you enter a StrikeRate of 0.0. Negative values of StrikeRate correspond to

Name	Description
	out-of-the-money swaptions, whereas positive values of StrikeRate correspond to in-the-money swaptions. • **AbsoluteStrike**: The strike of the option is just the input StrikeRate. *For example*, to set the strike at a swap rate of 5%, enter a value of 0.05 for StrikeRate. Since the yield curve generally changes at each time step, there is no way to ascertain the moneyness definitively of these swaptions. The calculations proceed as follows. First the swaption is priced (semi-)analytically based on the prevailing yield curve, and then calculation of the implied volatility is attempted. There are a few cases when this fails: • When the analytical swaption price is outside of the theoretical limits for option price, the implied volatility output is set to zero. This might come about because of tiny numerical inaccuracies in the numerical integration, most commonly when the option price is extremely small as might be the case when the option is far out-of-the-money or deep in-the-money. Alternatively it might arise because of negative interest rates leading to a negative underlying annuity price or a discount factor greater than 1.0. • When the swaption is sufficiently far out-of-the-money or sufficiently deep in-the-money such that the option price sensitivity to volatility (that is, the Greek known as Vega) is zero, the implied volatility output is set to zero. In these cases, there are a wide range of volatilities that reproduce the swaption price to the limits of machine precision, and hence any solution obtained from the calculations would not be unique.

Factor [VolatilityFactorMu]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The factors represent a principal component of the forward rate yield curve covariance matrix.

Input variables

Name	Description
FactorVolatility	A parameter set with volatilities for this factor. The number of entries in the parameter set should match the number of start rates for the LMMPlus.

NominalYieldCurve [TwoFactorHullWhite]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The TwoFactorHullWhite model is a two factor Gaussian short-rate model which can be initialized to fit an arbitrary time zero yield curve. The two factors are modeled as Ornstein-Uhlenbeck (also known as Vasicek) processes.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
InitialYieldCurve	The initial yield curve.
OneFactorVasicekHW1	A one-factor Vasicek model. Can be any of the following models: • OneFactorVasicekHW [OneFactorVasicekHW] • OneFactorVasicekHW [OneFactorVasicekTVTP] • OneFactorVasicekHW [OneFactorVasicekTD]
OneFactorVasicekHW2	A one-factor Vasicek model. Can be any of the following models: • OneFactorVasicekHW [OneFactorVasicekHW] • OneFactorVasicekHW [OneFactorVasicekTVTP] • OneFactorVasicekHW [OneFactorVasicekTD]

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash, with a starting value of 1.0. $\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate}(t-\Delta t)\Delta t)$ where CashTotalReturnIndex(0) = 1.
CashTotalReturn	The total return of cash over the time step. $\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)} - 1$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $\mathrm{AnnualisedCashTotalReturn}(t) = (1+\mathrm{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The continuously compounded nominal interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $\mathrm{ShortRate}(t) = \frac{-\ln(Z_N(Govt,\Delta t,t))}{\Delta t}$ where Δt is the simulation time step.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $\mathrm{AnnualisedShortRate}(t) = \exp(\mathrm{ShortRate.Value}(t)) - 1$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.

Name	Description
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \left(\frac{1}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}\right)^{\frac{1}{\mathrm{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \mathrm{CompoundingFrequency}, t) = \mathrm{CompoundingFrequency} \times \left\{(1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))^{\frac{1}{\mathrm{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\mathrm{CustomSpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, \infty, t) = \ln(1 + \mathrm{SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t))$$
ForwardRate [CreditClass, Maturity, Seniority]	The simply compounded one-year forward rate. Calculated using the formula: $$\mathrm{ForwardRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \frac{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t)}{\mathrm{ZCBP}(\mathrm{CreditClass}, \mathrm{Maturity} + 1, \mathrm{Seniority}, t)}$$ where the +1 in the denominator is because this is a one-year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\mathrm{AnnuityPrice}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) = \sum_{\tau=1}^{\mathrm{Maturity}} \mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority}, t)$$
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, \mathrm{CreditClass}, \tau, \mathrm{Seniority}) = f\,\frac{1 - \mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})}{\sum_{n=1}^{f\times\tau} \mathrm{ZCBP}\left(\mathrm{CreditClass}, \frac{n}{f}, \mathrm{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Zero Coupon Bond Martingale Test	Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.

Name	Description
Local Currency Zero Coupon Bond Martingale Test	Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Swaption Implied Volatility Test Abs [SwaptionType, AbsStrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The strike of the contract is calculated as the value of the **AbsStrikeRate** (absolute strike rate).
Swaption Implied Volatility Test Diff [SwaptionType, AbsStrRateDiff, SwapTenor, IncludeAnalyticVol]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The strike of the contract is calculated as forward swap rate of the contract, plus the **AbsStrRateDiff** (absolute strike rate difference). When you select this test, you can choose whether to output analytic swaption implied volatilities at time step 0.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.
Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]	Outputs time-zero swaption prices and implied volatilities with swaption maturities corresponding to each time step. The underlying swap has an annual payment frequency. Fill the following fields: • **SwaptionType**—Payer or Receiver.

Name	Description
	• **StrikeType**—This parameter, together with the StrikeRate, defines the strike of the option. Possible values: ◦ **ForwardStrike1**—The software calculates the swaption strike as the corresponding forward swap rate multiplied by the input StrikeRate. ◦ **ForwardStrike2**—The software calculates the swaption strike as the corresponding forward swap rate plus the input StrikeRate. ◦ **AbsoluteStrike**—The swaption strike equals the input StrikeRate. • **StrikeRate**—This parameter, together with the StrikeType determines the swaption strike rate. • **SwapTenor**—The tenor of the underlying swap. • **ImpliedVolatilityType**—The basis by which the implied volatility is reported. Possible values: ◦ **Lognormal**—The software quotes the volatility on a "displaced log-normal" basis. This assumes a displaced log-normal forward swap rate. If you use the preset value of zero for the Displacement, then a standard log-normal volatility is reported. ◦ **Normal**—The software quotes the volatility on an absolute basis, assuming a normally distributed forward swap rate. • **Displacement**—The displacement used for reporting swaption implied volatility. This parameter only affects the reported implied volatility if the ImpliedVolatilityType is Lognormal. • **SignificanceLevel**—The significance level used for reporting the confidence interval for estimated swaption implied volatility. The preset value, 0.05, corresponds to a 95% confidence interval. • **IncludeAnalyticVol**—To include analytical (model) volatility and price, select **True**.
Local Currency Swaption Test [SwaptionType, StrikeType, StrikeRate, SwapTenor, ImpliedVolatilityType, Displacement, SignificanceLevel, IncludeAnalyticVol]	A local currency version of the Swaption Test (described above) which uses the local economy's nominal yield curve to calculate prices (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.

InitialYieldCurve

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents the initial yield curve of the TwoFactorHullWhite model. The initial yield curve is specified with zero coupon bond prices at time zero. For more information about how the yield curve is interpolated, see the Scenario Generator Methodology Guide.

Input variables

Name	Description
InputYieldCurve	Specify the initial yield curve. Fill the following fields: • **Years**—The maturity time (measured in years) for the corresponding zero coupon bond. • **ZeroCouponBondPrice**—The zero coupon bond price for the specified maturity.

OneFactorVasicekHW [OneFactorVasicekHW]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents a one factor Vasicek process with piecewise-constant time-dependent volatility, as used in the TwoFactorHullWhite nominal yield curve. The process has an initial value of zero and a risk-neutral mean reversion level of zero.

Input variables

Name	Description	
RiskNeutralMeanReversionRate	The risk-neutral mean reversion rate of the stochastic process.	
Volatility	Fill the following fields: • **Years**—The time interval in years over which the corresponding volatility value applies. • **Volatility**—The volatility of the stochastic process.	
RealWorldMeanReversionRate	The real-world mean reversion rate of the stochastic process.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RealWorldMeanReversionLevel	The real-world mean reversion level.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The instantaneous value of the stochastic process.

OneFactorVasicekHW [OneFactorVasicekTVTP]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents a one-factor Vasicek process, used in the TwoFactorHullWhite nominal yield curve. The process has an initial value of zero and a risk-neutral mean reversion level of zero. For real-world simulations, the process has a smooth, time-varying term premium.

Input variables

Name	Description
MeanReversionRate	The mean reversion rate of the stochastic process.
Volatility	The volatility of the stochastic process.
Gamma	The time-varying market price of risk for the stochastic process.

Outputs

Name	Description
Value	The instantaneous value of the stochastic process.

OneFactorVasicekHW [OneFactorVasicekTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents a one-factor Vasicek process with time-dependent, piecewise-constant parameters, as used in the TwoFactorHullWhite nominal yield curve.

Note To use this model, both factors of the HullWhite model must be set to OneFactorVasicekTD and the Years input parameters of the two OneFactorVasicekTD factors are required to be identical.

Input variables

Name	Description
Parameters	Fill the following fields: • **Years**—The time interval in years over which the parameter values apply. • **RealWorldMeanReversionRate**—Mean-reversion rate of the stochastic process, under the real-world measure. Required only when running a real-world simulation. • **RealWorldMeanReversionLevel**—Mean-reversion level of the stochastic process, under the real-world measure. Required only when running a real-world simulation. • **Volatility**—Volatility of the stochastic process. • **RiskNeutralReversionRate**—Mean-reversion rate of the stochastic process, under the risk-neutral measure. • **RiskNeutralMeanReversionLevel**—Mean-reversion level of the stochastic process, under the risk-neutral measure. **Note** To run a real world simulation, set the simulation-level **UseRiskNeutralValuation** parameter to **False**.

Outputs

Name	Description
Value	The instantaneous value of the stochastic process.

NominalYieldCurve [ThreeFactorExtendedCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The ThreeFactorExtendedCIR model is a three factor short-rate model which can be initialized to fit an arbitrary time zero yield curve. The three factors are modeled as independent square-root (also known as Cox-Ingersoll-Ross) processes.

For more details about the yield curve models available in the Scenario Generator software, see the Yield Curves methodology.

Submodels

Name	Description
InitialYieldCurve	The initial yield curve. Possible values: • InitialYieldCurve [NAICYieldCurve] • InitialYieldCurve [DeterministicYieldCurve]
OneFactorCIR1 [ExtendedOneFactorCIRTD]	A one-factor CIR model with a piecewise-constant time-dependent parameter.
OneFactorCIR2 [ExtendedOneFactorCIRTD]	A one-factor CIR model with a piecewise-constant time-dependent parameter.
OneFactorCIR3 [ExtendedOneFactorCIRTD]	A one-factor CIR model with a piecewise-constant time-dependent parameter.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash, with a starting value of 1.0. $\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t - \Delta t)\exp(\mathrm{ShortRate}(t - \Delta t)\Delta t)$ where CashTotalReturnIndex(0) = 1.
CashTotalReturn	The total return of cash over the time step. $\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t - \Delta t)} - 1$ with CashTotalReturn(0) = 0.

Name	Description
	Note Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t) = (1 + \text{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The continuously compounded nominal interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the simulation time step.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $$\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$$
ForwardRate [CreditClass, Maturity, Seniority]	The simply compounded one-year forward rate. Calculated using the formula: $$\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + 1, \text{Seniority}, t)}$$ where the +1 in the denominator is because this is a one-year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$$

Name	Description
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, \mathrm{CreditClass}, \tau, \mathrm{Seniority}) = f\frac{1-\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})}{\sum_{n=1}^{f\times\tau}\mathrm{ZCBP}\left(\mathrm{CreditClass}, \frac{n}{f}, \mathrm{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Zero Coupon Bond Martingale Test	Outputs estimated prices of zero coupon bonds and the standard error of each estimate, alongside an analytic expected zero coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps.
Local Currency Zero Coupon Bond Martingale Test	Outputs estimated prices of zero-coupon bonds and the standard error of each estimate, alongside an analytic expected zero-coupon bond price for comparison purposes. The output maturities coincide with the simulation time steps. The prices are calculated using the nominal yield curve of the local economy (instead of the base economy of the simulation). The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Swaption Implied Volatility Test [SwaptionType, StrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The software calculates the strike of contract as the forward swap rate of the swaption contract, multiplied by the **StrikeRate**.
Swaption Implied Volatility Test Abs [SwaptionType, AbsStrikeRate, SwapTenor]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The strike of the contract is calculated as the value of the **AbsStrikeRate** (absolute strike rate).
Swaption Implied Volatility Test Diff [SwaptionType, AbsStrRateDiff, SwapTenor, IncludeAnalyticVol]	Outputs swaption prices and implied volatilities for a given **SwaptionType**, **Tenor**, and strike. The strike of the contract is calculated as forward swap rate of the contract, plus the **AbsStrRateDiff** (absolute strike rate difference). When you select this test, you can choose whether to output analytic swaption implied volatilities at time step 0.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond.

Name	Description
	• **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.

InitialYieldCurve [NAICYieldCurve]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents the initial yield curve of the ThreeFactorExtendedCIR model. The initial yield curve is specified as continuously-compounded spot rates. For more information about how the yield curve is interpolated, see the *Scenario Generator Methodology Guide*.

This model is available only when the simulation-level UseRiskNeutralValuation parameter is False and the StochasticRunType parameter is Stochastic. The model is supported for constant parameters only, so all three OneFactorCIR submodels must have exactly one row in the Parameters parameter set.

Input variables

Name	Description
InitialYieldCurve	The initial yield curve specified as continuously-compounded spot rates. Fill the following fields: • **Years**—The maturity time (measured in years) for the corresponding spot rate. • **SpotRate**—The spot rate for the specified maturity.
Displacement	The constant to apply to short rate calculations.
Decay	The speed of reversion to zero of the initial displacement applied to the short rate to match the initial yield curve.

InitialYieldCurve [DeterministicYieldCurve]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model represents the initial yield curve of the ThreeFactorExtendedCIR model. The initial yield curve is specified with zero coupon bond prices at time zero. For more information about how the yield curve is interpolated, see the Scenario Generator Methodology Guide.

Input variables

Name	Description
InitialYieldCurve	The initial yield curve in terms of zero coupon bond prices. Fill the following fields: • **Years**—The maturity time (measured in years) for the corresponding zero coupon bond. • **ZeroCouponBondPrice**—The zero coupon bond price for the specified maturity.

OneFactorCIR [ExtendedOneFactorCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A one-factor CIR model with piecewise-constant time-dependent parameters, as used in the ThreeFactorExtendedCIR nominal yield curve.

Input variables

Name	Description
Parameters	Fill the following fields: • **Years**—The time interval in years over which the parameter values apply. • **NrSubDivisions**—Number of Brownian bridge subdivisions over the associated year interval. Its value must be set so that for each time step of the simulation the number of Brownian bridge subdivisions over the time step does not exceed 240. • **MeanReversionRate**—Mean-reversion rate of the stochastic process, under the real-world measure. Required only when running a real-world simulation. If InitialYieldCurve is DeterministicYieldCurve, its value is floored at 10^{-4}. If InitialYieldCurve is NAICYieldCurve, its value is floored at 10^{-12}. • **MeanReversionLevel**—Mean-reversion level of the stochastic process, under the real-world measure. Required only when running a real-world simulation. • **Volatility**—Volatility of the stochastic process. If InitialYieldCurve is DeterministicYieldCurve, its value is floored at 10^{-4}. If InitialYieldCurve is NAICYieldCurve, its value is floored at 10^{-12}. • **RiskNeutralMeanReversionRate**—Mean-reversion rate of the stochastic process, under the risk-neutral measure. If InitialYieldCurve is DeterministicYieldCurve, its value is floored at 10^{-4}. If InitialYieldCurve is NAICYieldCurve, its value is floored at 10^{-12}. • **RiskNeutralMeanReversionLevel**—Mean-reversion level of the stochastic process, under the risk-neutral measure.

Name	Description
	Note To run a real world simulation, set the simulation-level **UseRiskNeutralValuation** parameter to **False**.
InitialValue	Starting value of the stochastic process.

Outputs

Name	Description
Value	The instantaneous value of the stochastic process.

NominalYieldCurve [DeterministicYieldCurve]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A deterministic yield curve model. The model is evolved through time by realizing forward rates implied from the input yield curve, which is specified with zero coupon bond prices at time zero. For more details on how the Scenario Generator software interpolates the input yield curve, see the DeterministicYieldCurve methodology.

Note Do not use the deterministic yield curve as the main yield curve model.

Input variables

Name	Description
InputYieldCurve	Fill the following fields: • **Years**—The maturity time (measured in years) for the corresponding zero coupon bond. • **ZeroCouponBondPrice**—The zero coupon bond price for the specified maturity.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash, with a starting value of 1.0. $\mathrm{CashTotalReturnIndex}(t) = \mathrm{CashTotalReturnIndex}(t-\Delta t)\exp(\mathrm{ShortRate}(t-\Delta t)\Delta t)$ where CashTotalReturnIndex(0) = 1.
CashTotalReturn	The total return of cash over the time step. $\mathrm{CashTotalReturn}(t) = \frac{\mathrm{CashTotalReturnIndex}(t)}{\mathrm{CashTotalReturnIndex}(t-\Delta t)} - 1$ with CashTotalReturn(0) = 0.

Name	Description
	Note Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
AnnualisedCashTotalReturn	The annualized cash total return. $$\text{AnnualisedCashTotalReturn}(t) = (1 + \text{CashTotalReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ShortRate	The continuously compounded nominal interest rate that applies to a very short period. This output is calculated from the zero coupon bond prices as: $$\text{ShortRate}(t) = \frac{-\ln(Z_N(Govt, \Delta t, t))}{\Delta t}$$ where Δt is the simulation time step.
AnnualisedShortRate	The annually compounded short rate. Calculated using the equation $$\text{AnnualisedShortRate}(t) = \exp(\text{ShortRate.Value}(t)) - 1$$
ZCBP [CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. This output is calculated in different ways depending on the interest rate model that is chosen.
SpotRate [CreditClass, Maturity, Seniority]	The annually compounded spot rate. Calculated using the formula: $$\text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \left(\frac{1}{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}\right)^{\frac{1}{\text{Maturity}}} - 1$$
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t) = \text{CompoundingFrequency} \times \left\{(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1\right\}$$ And for continuous compounding: $$\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t) = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))$$
ForwardRate [CreditClass, Maturity, Seniority]	The simply compounded one-year forward rate. Calculated using the formula: $$\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + 1, \text{Seniority}, t)}$$ where the +1 in the denominator is because this is a one-year forward rate.
AnnuityPrice [CreditClass, Maturity, Seniority]	The price of an annuity with a specified maturity, and one payment per annum. Calculated using the formula: $$\text{AnnuityPrice}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \sum_{\tau=1}^{\text{Maturity}} \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority}, t)$$

Name	Description
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, \mathrm{CreditClass}, \tau, \mathrm{Seniority}) = f\frac{1 - \mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})}{\sum_{n=1}^{f\times\tau} \mathrm{ZCBP}\left(\mathrm{CreditClass}, \frac{n}{f}, \mathrm{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\mathrm{ZCBP}(\mathrm{CreditClass}, \tau, \mathrm{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

Analysis tests

Name	Description
Initial Nominal Yield Curve [MaximumMaturityYears]	Outputs the time zero yield curve. The yield curve is expressed equivalently in terms of zero coupon bond prices and annually compounded spot rates.
Bond Market Instrument Test [Name, CreditClass, Seniority, Term, Coupon, Frequency]	Outputs the time zero prices of the bonds that you define. Also calculates the annually compounded bond yields. After selecting the test, enter the following values for each bond: • **Name**—A name for the bond. • **CreditClass**—The credit class for the bond issuer. • **Seniority**—The seniority of the bond. • **Term**—The term of the bond. • **Coupon**—The coupon for the bond. • **Frequency**—The number of coupon payments per year. **Note** If you enter multiple bonds, each appears as a separate line in the Selected list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.
Swap Market Instrument Test [Name, Term, Frequency]	Outputs time zero par swap rates. The swap rates that the software outputs are expressed annually. After selecting the test, enter the following values for each swap: • **Name**—A name for the swap. • **Term**—The number of years of the swap. • **Frequency**—The number of swap payments per year. **Note** If you enter multiple swaps, each appears as a separate line in the **Selected** list. However, the application saves all the swaps that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first swap that you define.

NominalYieldCurve [YieldCurvePlusSpread] and [YieldCurveMinusSpread]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The YieldCurvePlusSpread and YieldCurveMinusSpread models take two other nominal yield curve models (set up in advance of configuring this model) and combine them to create a custom curve.

These models are designed for Real World modeling and are not compatible with simulations where the **UseRiskNeutralValuation** parameter is set to True.

Input variables

Name	Description
SpreadModel	Choice from the yield curves already set up under the NominalYieldCurve node. The software uses this model to create spread.
YieldCurve	Choice from the yield curves already set up under the NominalYieldCurve node. The software uses this model to provide the base.
InitialIndexValue	The base value for index outputs.

Note ActuarialInterestRate models and other YieldCurvePlusSpread or YieldCurveMinusSpread models cannot be selected under the YieldCurve or SpreadModel parameters of these models.

Outputs

Name	Description
CashTotalReturnIndex	The total return index of cash. $\text{CashTotalReturnIndex}(0) = \text{InitialIndexValue}$
CashTotalReturn	The total return of cash over the time step. $\text{CashTotalReturn}(t) = \dfrac{\text{CashTotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t - \Delta t)} - 1$ with CashTotalReturn(0) = 0. **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
ZCBP[CreditClass, Maturity, Seniority]	The zero coupon bond price for the specified credit class, maturity, and seniority. $\text{ZCBP}[\text{CreditClass}, \text{Maturity}, \text{Seniority}, t] = (1 + \text{SpotRate}[\text{CreditClass}, \text{Maturity}, \text{Seniority}, t])^{-\text{Maturity}}$
SpotRate [CreditClass, Maturity, Seniority]	For the YieldCurvePlusSpread model: $\text{SpotRate}[\text{CreditClass}, \text{Maturity}, \text{Seniority}, t] = (1 + \text{YieldCurve.SpotRate}[\text{CreditClass}, \text{Maturity}, \text{Seniority}, t]) \times (1 + \text{SpreadModel.SpotRate}[\text{Govt}, \text{Maturity}, \text{Seniority}, t]) - 1$ For the YieldCurveMinusSpread model: $\text{SpotRate}[\text{CreditClass}, \text{Maturity}, \text{Seniority}, t] = \dfrac{(1 + \text{YieldCurve.SpotRate}[\text{CreditClass}, \text{Maturity}, \text{Seniority}, t])}{(1 + \text{SpreadModel.SpotRate}[\text{Govt}, \text{Maturity}, \text{Seniority}, t])} - 1$

Name	Description
CustomSpotRate [CreditClass, Maturity, Seniority, CompoundingFrequency]	The spot rate with a compounding frequency that you define. $$\begin{aligned}&\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \text{CompoundingFrequency}, t)\\ &\quad = \text{CompoundingFrequency}\\ &\quad \times \left\{ (1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))^{\frac{1}{\text{CompoundingFrequency}}} - 1 \right\}\end{aligned}$$ And for continuous compounding: $$\begin{aligned}&\text{CustomSpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, \infty, t)\\ &\quad = \ln(1 + \text{SpotRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))\end{aligned}$$
ForwardRate [CreditClass, Maturity, Seniority]	The simply compounded one-year forward rate. Calculated using the formula: $$\begin{aligned}&\text{ForwardRate}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)\\ &\quad = \frac{\text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)}{\text{ZCBP}(\text{CreditClass}, \text{Maturity} + 1, \text{Seniority}, t)}\end{aligned}$$ where the +1 in the denominator is because this is a one-year forward rate.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\text{ParYield}(f, \text{CreditClass}, \tau, \text{Seniority}) = f\frac{1 - \text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})}{\sum_{n=1}^{f\times\tau} \text{ZCBP}\left(\text{CreditClass}, \frac{n}{f}, \text{Seniority}\right)}$$ where: • f is the frequency. • τ is the maturity. • $\text{ZCBP}(\text{CreditClass}, \tau, \text{Seniority})$ is the zero coupon bond price based on this nominal yield curve and the primary credit model for this economy.

3.1.3 InflationRates

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The Scenario Generator software contains models for core inflation and alternative inflation indices. Only one core inflation model can be used (although its type can be changed) but there can be any number of inflation wedge and alternative inflation models.

For more information about inflation modeling in the Scenario Generator software, see the Inflation Modeling methodology.

Submodels

Name	Description
Inflation	Models the core inflation rate and can be changed to be any of the following variants: • Inflation [DerivedInterestRate] • Inflation [InflationPlus]

Addable submodels

Name	Description
InflationWedge	This submodel is a one factor Vasicek model which allows the modeling of additional inflation rates. *For example*, medical or wage.
AlternativeInflation	This submodel is an InflationPlus model with an editable RealYieldCurve and NominalYieldCurve parameter, enabling you to create alternative inflation measures.

Inflation [DerivedInterestRate]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Using this model, the core inflation is derived from nominal and real interest rates only. The correlation between nominal and real rates partly controls the inflation distribution. This model has no direct input parameters, other than the inputs to the interest rate models themselves.

For more information about inflation modeling in the Scenario Generator software, see the Inflation Modeling methodology.

In what follows, Δt represents the time step (assuming this is uniform throughout the simulation), $Z_N(t,\tau)$ is the price of a risk-free nominal zero coupon bond at time t with term to maturity τ, and $Z_R(t,\tau)$ is the price of the equivalent risk-free index-linked bond.

Input variables

Name	Description
InitialIndexValue	The base value for index outputs.
InitialInflationRate	The time zero value for inflation rate. The preset value is 0.

Outputs

Name	Description
Rate	The annually compounded inflation rate that applies over the previous time step. $$\text{Rate}(t) = \exp\left(\begin{array}{c}\text{Nominal.ShortRate}(t-\Delta t)\\ -\frac{1}{2}(\text{Real.ShortRate}(t-\Delta t)+\text{Real.ShortRate}(t))\end{array}\right)-1$$ where Real.ShortRate and Nominal.ShortRate are the continuously compounded short rate outputs from the real and primary nominal yield curve models for this economy, respectively. $$\text{Rate}(0) = \text{InitialInflationRate}$$
InstantaneousRate	The annually compounded instantaneous inflation rate. $$\text{InstantaneousRate}(t) = \exp(\text{Nominal.ShortRate}(t) - \text{Real.ShortRate}(t)) - 1$$
Index	The inflation index. $$\text{Index}(t) = \text{Index}(t-\Delta t)(1+\text{Rate}(t))^{\Delta t}$$ where Index(0) = InitialIndexValue.
Change	The relative change in the inflation index since the last output. $$\text{Change}(n\Delta t) = \begin{cases} 0, & n = 0,\\ \frac{\text{Index}(n\Delta t)}{\text{Index}((n-1)\Delta t)} - 1, & \text{otherwise.}\end{cases}$$ where n is the number of steps between output data.
AnnualisedChange	The annualized change. $$\text{AnnualisedChange}(n\Delta t) = \begin{cases} 0, & n = 1,\\ (1+\text{Change}(n\Delta t))^{\frac{1}{(n\Delta t)}} - 1, & n > 0.\end{cases}$$
MedicalRate [Multiplier]	The annually compounded medical inflation rate. This output is linked to the Rate output by the input multiplier as follows: $$\text{MedicalRate}(t, m) = m(1+\text{Rate}(t)) - 1$$ where m := Multiplier.
SpotExpectation [Maturity]	The annually compounded spot (expected) inflation rate at the given maturity. SpotExpectation is the spread between nominal and real spot rates, and satisfies the equation $$(1+\text{SpotExpectation}(t,\tau))^{-\tau} = \frac{Z_N(t,\tau)}{Z_R(t,\tau)}$$ where τ := Maturity, with $Z_N(t,\tau)$ and $Z_R(t,\tau)$ defined as preceding.
ForwardExpectation [Maturity]	The annually compounded forward inflation rate at the given maturity, applied over a one-year period, as implied by the nominal and real yield curves. The forward expectation satisfies the equation $$\begin{aligned}(1+&\text{ForwardExpectation}(t,\tau))\\ &= \frac{Z_N(t,\tau)/Z_N(t,\tau+1)}{Z_R(t,\tau)/Z_R(t,\tau+1)}\\ &= \frac{(1+\text{SpotExpectation}(t,\tau+1))^{\tau+1}}{(1+\text{SpotExpectation}(t,\tau))^{\tau}}\end{aligned}$$ where τ := Maturity, with $Z_N(t,\tau)$ and $Z_R(t,\tau)$ defined as preceding.

Inflation [InflationPlus]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Using this model, inflation is derived from nominal and real interest rates and an additional unexpected inflation. The correlation between nominal and real rates partly controls the inflation distribution, as well as any correlation between the unexpected inflation shock and the interest rates. When using InflationPlus for risk-neutral simulations, index-linked bonds fail martingale tests unless the correlation between inflation shock and real rates shocks is zero. Index-linked bond pricing equations make the assumption that there are zero correlations between the unexpected inflation shock and other model shocks, and the introduction of non-zero correlations causes the failure of martingale tests.

For more information about inflation modeling in the Scenario Generator software, see the Inflation Modeling methodology.

In what follows, Δt represents the time step (assuming this is uniform throughout the simulation), $Z_N(t,\tau)$ is the price of a risk-free nominal zero coupon bond at time t with term to maturity τ, and $Z_R(t,\tau)$ is the price of the equivalent risk-free real zero coupon bond (priced using the real yield curve).

Submodels

Name	Description
Volatility [FixedVolatility]	A submodel governing the volatility of the unexpected inflation shocks. This model is a fixed volatility model.
MeanUnexpectedInflation	Specifies the mean level of unexpected inflation. This model is used only in real-world simulations, that is, the simulation-level UseRiskNeutralValuation parameter is False. This submodel can be one of the following: • MeanUnexpectedInflation [MeanUnexpectedInflationConstant] • MeanUnexpectedInflation [MeanUnexpectedInflationTD]

Input variables

Name	Description
InitialIndexValue	The base value for index outputs.
InitialInflationRate	The time zero value for inflation rate. The preset value is 0.

Outputs

Name	Description
Rate	The annually compounded (realized) rate of inflation, including expected and unexpected components. Rate(t) can be separated into its expected and unexpected parts as follows: $1 + \mathrm{Rate}(t) = (1 + \mathrm{ExpectedRate}(t - \Delta t))(1 + \mathrm{UnexpectedRate}(t))$ $\mathrm{Rate}(0) = \mathrm{InitialInflationRate}$

Name	Description
ExpectedRate	The annually compounded rate of inflation that is expected to occur over the next time step. This output is derived from the difference between continuously compounded real and nominal spot rates. In terms of zero coupon bonds, the expected rate satisfies the equation $$(1+\text{ExpectedRate}(t))^{\Delta t}=\frac{Z_R(t,\Delta t)}{Z_N(t,\Delta t)}$$ where $Z_N(t,\tau)$ and $Z_R(t,\tau)$ are defined as preceding.
UnexpectedRate	The annually compounded rate by which the realized inflation rate differs from the expected inflation rate. The unexpected rate satisfies the equation $$(1+\text{UnexpectedRate}(t))^{\Delta t}=(1+\text{MUI})^{\Delta t}\exp\left(-\frac{1}{2}\sigma^2\Delta t+\sigma\sqrt{\Delta t}\mathrm{d}Z(t)\right)$$ where: • MUI is the MeanUnexpectedInflation input. • σ is the Volatility input.
MeanUnexpectedRate	The annually compounded, annualized mean unexpected rate of inflation.
Index	The inflation index. The index starts with Index(0) = InitialIndexValue and the updating equation is $$\text{Index}(t)=\text{Index}(t-\Delta t)(1+\text{Rate}(t))^{\Delta t}$$
Change	The relative change in the inflation index since the last output. $$\text{Change}(n\Delta t)=\begin{cases}0, & n=0,\\ \frac{\text{Index}(n\Delta t)}{\text{Index}((n-1)\Delta t)}-1, & \text{otherwise.}\end{cases}$$ where n is the number of steps between output data.
AnnualisedChange	The annualized change. $$\text{AnnualisedChange}(n\Delta t)=\begin{cases}0, & n=1,\\ (1+\text{Change}(n\Delta t))^{\frac{1}{(n\Delta t)}}-1, & n>0.\end{cases}$$
MedicalRate [Multiplier]	The annually compounded medical inflation rate. This output is linked to the Rate output by the input multiplier as follows: $$\text{MedicalRate}(t,m)=m(1+\text{Rate}(t))-1$$ where m := Multiplier.
SpotExpectation [Maturity]	The annually compounded spot (expected) inflation rate at the given maturity. SpotExpectation is the spread between nominal and real spot rates, and satisfies the equation $$(1+\text{SpotExpectation}(t,\tau))^{-\tau}=\frac{Z_N(t,\tau)}{Z_R(t,\tau)}$$ where τ := Maturity, with $Z_N(t,\tau)$ and $Z_R(t,\tau)$ defined as preceding.

Name	Description
ForwardExpectation [Maturity]	The annually compounded forward inflation rate at the given maturity, applied over a one-year period, as implied by the nominal and real yield curves. The forward expectation satisfies the equation $$\begin{aligned}(1 + \mathrm{ForwardExpectation}(t,\tau)) \\ &= \frac{Z_N(t,\tau)/Z_N(t,\tau+1)}{Z_R(t,\tau)/Z_R(t,\tau+1)} \\ &= \frac{(1+\mathrm{SpotExpectation}(t,\tau+1))^{\tau+1}}{(1+\mathrm{SpotExpectation}(t,\tau))^{\tau}}\end{aligned}$$ where τ := Maturity, with $Z_N(t,\tau)$ and $Z_R(t,\tau)$ defined as preceding.

Volatility [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model governing the volatility of the unexpected inflation shocks.

Input variables

Name	Description
Value	The fixed volatility of the unexpected inflation shocks.

Outputs

Name	Description
Volatility	The volatility of the unexpected inflation shocks. For the fixed volatility model, this output is the same as the input value.

MeanUnexpectedInflation [MeanUnexpectedInflationConstant]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A constant mean unexpected inflation model.

Input variables

Name	Description
Value	The annually compounded mean level of the unexpected inflation.

Outputs

Name	Description
Value	The annually compounded value of the mean of the unexpected inflation. **Note** This output is equal to the **Value** input.

MeanUnexpectedInflation [MeanUnexpectedInflationTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A time-dependent mean unexpected inflation model.

Input variables

Name	Description	Condition
MeanUnexpectedInflation	The mean of the unexpected inflation. Fill the following fields: • **Years**—The time period, in years, to which this mean unexpected inflation applies. • **MeanUnexpectedInflation**—The annually compounded mean level of the unexpected inflation for this time period.	
Smoothing	Select whether you want to apply smoothing to the mean unexpected inflation.	
InitialMeanUnexpectedInflation	The initial mean of the unexpected inflation.	Enabled only if **Smoothing** is **True**.

Outputs

Name	Description
Value	The annually compounded value of the mean of the unexpected inflation.

InflationWedge

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

You can model alternative inflation rates using an *inflation wedge*. Inflation wedges are specified as normally distributed mean reverting processes, w_t , which represent a continuously compounded rate of inflation measured in excess of the core inflation model. For more information about the dynamics of the inflation wedge, see the Inflation Wedges methodology.

Input variables

Name	Description
Alpha	The speed of mean reversion of the inflation wedge.
Sigma	The volatility of the inflation wedge.
Mu	The mean reversion level of the inflation wedge.
StartVal	The initial value of the inflation wedge.

Outputs

Name	Description
Rate	The annually compounded rate of wedge inflation over the previous time step. At each simulation time t_n the software calculates this output as $$\mathrm{Rate}\,(t_n) := \exp\left(w_{t_n}\right) - 1$$ where w_{t_n} is the wedge value at time t_n. For information about how the wedge value is updated at each time step, see the Inflation Wedges methodology.
Index	The wedge index, calculated using the formula: $$\mathrm{Index}(t_n) = \mathrm{Index}(t_{n-1})(1 + \mathrm{Rate}(t_n))^{\Delta t_n} = \mathrm{Index}(t_{n-1})\exp\left(w_{t_n}\Delta t_n\right)$$ with Index(0) = 1.
Change	The relative change in the wedge inflation index since the last output. $$\mathrm{Change}(t_n) = \begin{cases} 0, & n = 0, \\ \frac{\mathrm{Index}(t_n)}{\mathrm{Index}(t_m)} - 1, & \text{otherwise.} \end{cases}$$ where *m* is the last time index at which this information was output, as determined by the file output frequency.
CombinedIndex	The combined index of the wedge inflation and core inflation. $$\begin{aligned}\mathrm{CombinedIndex}(t_n) &= \mathrm{Core.Index}(t_n)\mathrm{Index}(t_n) \\ &= \mathrm{CombinedIndex}(t_{n-1})(1 + \mathrm{Core.Rate}(t_n))^{\Delta t_n}(1 + \mathrm{Rate}(t_n))^{\Delta t_n}\end{aligned}$$ with CombinedIndex(0) = Core.Index(0), where Core.Index and Core.Rate are the Index and Rate outputs, respectively, of the core inflation model.
CombinedChange	The relative change in the combined index of wedge inflation and core inflation since the last output. $$\mathrm{CombinedChange}(t_n) := \begin{cases} 0, & n = 0, \\ \frac{\mathrm{CombinedIndex}(t_n)}{\mathrm{CombinedIndex}(t_m)} - 1, & \text{otherwise} \end{cases}$$ where *m* is the last time index at which this information was output, as determined by the file output frequency.

Name	Description
ExpectedRate	The annually compounded rate of wedge inflation that is expected to occur over the next time step. $$\text{ExpectedRate}(t_n) := \text{E}_{\mathbb{P}}\left[\frac{\text{Index}(t_{n+1})}{\text{Index}(t_n)}\middle\vert \mathcal{F}_{t_n}\right]^{\frac{1}{\Delta t_{n+1}}} - 1 = \text{E}_{\mathbb{P}}\left[\exp(w_{t_{n+1}}\Delta t_{n+1})\middle\vert \mathcal{F}_{t_n}\right]^{\frac{1}{\Delta t_{n+1}}} - 1$$ For information about the moment generating function which allows the calculation of the conditional expectation on the right-hand-side of the last equation, see the Scenario Generator Methodology Guide.
CombinedExpectedRate	The annually compounded rate of combined inflation that is expected to occur over the next time step. $$\text{CombinedExpectedRate}(t_n) := \text{E}_{\mathbb{P}}\left[\frac{\text{CombinedIndex}(t_{n+1})}{\text{CombinedIndex}(t_n)}\middle\vert \mathcal{F}_{t_n}\right]^{\frac{1}{\Delta t_{n+1}}} - 1 = (1+\text{ExpectedRate}(t_n))(1+\text{Core.ExpectedRate}(t_n)) - 1$$ where Core.ExpectedRate is the ExpectedRate output of the core inflation model, which coincides with InstantaneousRate if the core inflation is the DerivedInterest model.

AlternativeInflation

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The software models alternative inflation using Inflation Plus, which is also a modeling option for core inflation. However, the AlternativeInflation model enables you to select the nominal and real yield curves that are used to derive inflation.

Using this model, inflation is derived from nominal and real interest rates, using yield curves that you specify, and an additional unexpected inflation. The correlation between nominal and real rates partly controls the inflation distribution, as well as any correlation between the unexpected inflation shock and the interest rates. When using this model for risk-neutral simulations, index-linked bonds fail martingale tests unless the correlation between inflation shock and real rates shocks is zero. Index-linked bond pricing equations make the assumption that there are zero correlations between the unexpected inflation shock and other model shocks, and the introduction of non-zero correlations causes the failure of martingale tests.

For more information about inflation modeling in the Scenario Generator software, see the Inflation Modeling methodology.

In what follows, Δt represents the time step (assuming this is uniform throughout the simulation), $Z_N(t,\tau)$ is the price of a risk-free nominal zero coupon bond at time t with term to maturity τ, and $Z_R(t,\tau)$ is the price of the equivalent risk-free real zero coupon bond (priced using the real yield curve).

Submodels

Name	Description
Volatility [FixedVolatility]	A submodel governing the volatility of the unexpected inflation shocks. This model is a fixed volatility model.

Name	Description
MeanUnexpectedInflation	Specifies the mean level of unexpected inflation. This model is used only in real-world simulations, that is, the simulation-level UseRiskNeutralValuation parameter is False. This submodel can be one of the following: • MeanUnexpectedInflation [MeanUnexpectedInflationConstant] • MeanUnexpectedInflation [MeanUnexpectedInflationTD]

Input variables

Name	Description
NominalYieldCurve	From the drop-down list, select a nominal yield curve.
RealYieldCurve	From the drop-down list, select a real yield curve.
InitialIndexValue	The base value for index outputs.
InitialInflationRate	The time zero value for inflation rate. The preset value is 0.

Outputs

Name	Description
Rate	The annually compounded (realized) rate of inflation, including expected and unexpected components. Rate(t) can be separated into its expected and unexpected parts as follows: $1 + \mathrm{Rate}(t) = (1 + \mathrm{ExpectedRate}(t - \Delta t))(1 + \mathrm{UnexpectedRate}(t))$ $\mathrm{Rate}(0) = \mathrm{InitialInflationRate}$
ExpectedRate	The annually compounded rate of inflation that is expected to occur over the next time step. This output is derived from the difference between continuously compounded real and nominal spot rates. In terms of zero coupon bonds, the expected rate satisfies the equation $(1 + \mathrm{ExpectedRate}(t))^{\Delta t} = \frac{Z_R(t, \Delta t)}{Z_N(t, \Delta t)}$ where $Z_N(t,\tau)$ and $Z_R(t,\tau)$ are defined as preceding.
UnexpectedRate	The annually compounded rate by which the realized inflation rate differs from the expected inflation rate. The unexpected rate satisfies the equation $(1 + \mathrm{UnexpectedRate}(t))^{\Delta t} = (1 + \mathrm{MUI})^{\Delta t} \exp\left(-\frac{1}{2}\sigma^2 \Delta t + \sigma\sqrt{\Delta t}\mathrm{d}Z(t)\right)$ where: • MUI is the MeanUnexpectedInflation input. • σ is the Volatility input.
MeanUnexpectedRate	The annually compounded, annualized mean unexpected rate of inflation.
Index	The inflation index. The index starts with Index(0) = InitialIndexValue and the updating equation is $\mathrm{Index}(t) = \mathrm{Index}(t - \Delta t)(1 + \mathrm{Rate}(t))^{\Delta t}$

Name	Description
Change	The relative change in the inflation index since the last output. $$\text{Change}(n\Delta t) = \begin{cases} 0, & n = 0, \\ \frac{\text{Index}(n\Delta t)}{\text{Index}((n-1)\Delta t)} - 1, & \text{otherwise.} \end{cases}$$ where n is the number of steps between output data.
AnnualisedChange	The annualized change. $$\text{AnnualisedChange}(n\Delta t) = \begin{cases} 0, & n = 1, \\ (1 + \text{Change}(n\Delta t))^{\frac{1}{(n\Delta t)}} - 1, & n > 0. \end{cases}$$
MedicalRate [Multiplier]	The annually compounded medical inflation rate. This output is linked to the Rate output by the input multiplier as follows: $$\text{MedicalRate}(t, m) = m(1 + \text{Rate}(t)) - 1$$ where m := Multiplier.
SpotExpectation [Maturity]	The annually compounded spot (expected) inflation rate at the given maturity. SpotExpectation is the spread between nominal and real spot rates, and satisfies the equation $$(1 + \text{SpotExpectation}(t, \tau))^{-\tau} = \frac{Z_N(t, \tau)}{Z_R(t, \tau)}$$ where τ := Maturity, with $Z_N(t,\tau)$ and $Z_R(t,\tau)$ defined as preceding.
ForwardExpectation [Maturity]	The annually compounded forward inflation rate at the given maturity, applied over a one-year period, as implied by the nominal and real yield curves. The forward expectation satisfies the equation $$\begin{aligned}(1 + \text{ForwardExpectation}(t, \tau)) &= \frac{Z_N(t, \tau)/Z_N(t, \tau + 1)}{Z_R(t, \tau)/Z_R(t, \tau + 1)} \\ &= \frac{(1 + \text{SpotExpectation}(t, \tau + 1))^{\tau+1}}{(1 + \text{SpotExpectation}(t, \tau))^{\tau}}\end{aligned}$$ where τ := Maturity, with $Z_N(t,\tau)$ and $Z_R(t,\tau)$ defined as preceding.

Volatility [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model governing the volatility of the unexpected inflation shocks.

Input variables

Name	Description
Value	The fixed volatility of the unexpected inflation shocks.

Outputs

Name	Description
Volatility	The volatility of the unexpected inflation shocks. For the fixed volatility model, this output is the same as the input value.

MeanUnexpectedInflation [MeanUnexpectedInflationConstant]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A constant mean unexpected inflation model.

Input variables

Name	Description
Value	The annually compounded mean level of the unexpected inflation.

Outputs

Name	Description
Value	The annually compounded value of the mean of the unexpected inflation. **Note** This output is equal to the **Value** input.

MeanUnexpectedInflation [MeanUnexpectedInflationTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A time-dependent mean unexpected inflation model.

Input variables

Name	Description	Condition
MeanUnexpectedInflation	The mean of the unexpected inflation. Fill the following fields: • **Years**—The time period, in years, to which this mean unexpected inflation applies. • **MeanUnexpectedInflation**—The annually compounded mean level of the unexpected inflation for this time period.	

Name	Description	Condition
Smoothing	Select whether you want to apply smoothing to the mean unexpected inflation.	
InitialMeanUnexpectedInflation	The initial mean of the unexpected inflation.	Enabled only if **Smoothing** is **True**.

Outputs

Name	Description
Value	The annually compounded value of the mean of the unexpected inflation.

3.1.4 ExchangeRate [ExchangeRate]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

All modeled exchange rates are specified with reference to some base currency. For more information about where to find the BaseEconomy parameter, see Simulation. For more information about setting the base economy, see the Specifying the Base Economy user guide section.

The exchange rate model that the ESG uses depends on your value for UseRiskNeutralValuation in the Simulation model and for AssumeRiskNeutralDynamics in the ExchangeRate model, as described in the following table.

Exchange rate model selection

UseRiskNeutralValuation setting	AssumeRiskNeutralDynamics setting	Model used by software
True	N/A	Interest rate parity (IRP)
False	True	IRP model with a risk premium
False	False	Purchasing power parity

If you select the ExchangeRate [ExchangeRate] model, the RSG uses the purchasing power parity model.

You can also directly change the model type to ExchangeRate [PurchasingPowerParity] or ExchangeRate [InterestRateParity]. These models also enable you to select from a fixed or time-varying market price of risk.

For more information about exchange rate modeling in the software, see the Exchange Rate methodology.

Submodels

Name	Description
Volatility	The proportional volatility of the exchange rate process.

Input variables

Name	Description	Availability	Conditions
Alpha	The speed of mean reversion of the exchange rate. Used if UseRiskNeutralValuation is False and AssumeRiskNeutralDynamics is False.		
Mu	The exponential of the mean reversion level of the log real exchange rate. Used if UseRiskNeutralValuation is False and AssumeRiskNeutralDynamics is False.		
StartVal	The common initial value of both the nominal and real exchange rates with respect to a reference economy.		
AssumeRiskNeutralDynamics	If UseRiskNeutralValuation is False, this parameter determines the type of exchange rate model to use. Possible values: • **True**—The software uses an interest rate parity (IRP) exchange rate model. The drift of the nominal exchange rate is set to the difference between nominal short rate in this economy and the nominal short rate in the base economy. In this case, cash in this economy is expected to earn the base currency cash rate, when exchanged into the base currency. • **False**—The software uses a purchasing power parity (PPP) exchange rate model. The nominal exchange rate is assumed to mean-revert towards purchasing power parity.	ESG	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
MarketPriceOfRisk	The market price of risk used for real-world simulation under the IRP model. Used if UseRiskNeutralValuation is False and AssumeRiskNeutralDynamics is True.		

Outputs

Name	Description
RealValue	The number of units of this currency, per unit of currency of the base economy in real terms. Under real-world dynamics, this value is calculated using the exact solution of the stochastic differential equation for Y^t: $$\mathrm{RealValue}(0) = \frac{\mathrm{StartVal}}{\mathrm{Base.StartVal}}$$ and $$\ln(\mathrm{RealValue}(t)) = \ln\widehat{\mathrm{Mu}} + \exp(-\mathrm{Alpha}\ \Delta t)(\ln(\mathrm{RealValue}(t-\Delta t) - \ln\widehat{\mathrm{Mu}}) - \mathrm{Vol}\ \mathrm{dZ}(t)$$ where $$\widehat{\mathrm{Mu}} := \frac{\mathrm{Mu}}{\mathrm{Base.Mu}}$$ and Base.StartVal and Base.Mu are the values of these parameters for the base economy, and $$\mathrm{Vol} := \begin{cases} \sqrt{\left(\frac{\mathrm{Sigma}^2}{2\mathrm{Alpha}}(1-\exp(-2\mathrm{Alpha}\Delta t))\right)}, & \mathrm{Alpha} \neq 0, \\ 0, & \mathrm{Alpha} = 0 \end{cases}$$ and Sigma:= Volatility.Value. Under risk-neutral dynamics the real exchange rate value is derived from the nominal exchange rate value as follows: $$\mathrm{RealValue}(t) = \mathrm{NominalValue}(t)\frac{\mathrm{Base.Inflation.Index}(t)}{\mathrm{Inflation.Index}(t)}$$ where Base.Inflation.Index is the inflation index of the base economy.
NominalValue	The number of units, X_t, of this currency per unit of currency of the base economy. Equivalently, the price of one unit of base currency in units of this economy's currency. For more information, see the Scenario Generator Methodology Guide.
NominalReturn	The return over the last time step on a unit of this currency for a base economy investor. Calculated using the formula: $$\mathrm{NominalReturn}(t) = \frac{\mathrm{NominalValue}(t)}{\mathrm{NominalValue}(t-1)} - 1$$
InverseRealValue	The number of units of the base economy's currency per unit of this currency in real terms.
InverseNominalValue	The number of units of the base economy's currency per unit of this currency. Equivalently, the price of one unit of this currency in units of the base currency.
RealValueForEconomy [Economy]	The number of units of the currency of this economy per unit of the currency of the selected Economy in real terms.
NominalValueForEconomy [Economy]	The number of units of the currency of this economy per unit of the currency of the selected Economy.
InverseRealValueForEconomy [Economy]	The number of units of the selected Economy's currency per unit of the currency of this economy in real terms.
InverseNominalValueForEconomy [Economy]	The number of units of the selected Economy's currency per unit of the currency of this economy.

Volatility [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model prescribing the exchange rate process to have a fixed amount of volatility.

Input variables

Name	Description
Value	The fixed volatility of the exchange rate process.

Outputs

Name	Description
Volatility	The volatility of the exchange rate shocks. For the fixed volatility model, this output is the same as the input value.

3.1.5 ExchangeRate [PurchasingPowerParity]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A purchasing power parity exchange rate model.

Submodels

Name	Description
Volatility [FixedVolatility]	A model prescribing the exchange rate process to have a fixed amount of volatility.
MarketPriceOfRisk	The market price of risk. Possible models: • MarketPriceOfRisk [ConstantMarketPriceOfRisk] • MarketPriceOfRisk [TimeVaryingMarketPriceOfRisk]

Input variables

Name	Description	Condition
Alpha	The speed of mean reversion of the log real exchange rate.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
Mu	The mean reversion level of the log real exchange rate.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Name	Description	Condition
StartVal	The common initial value of both the nominal and real exchange rates.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
Inflation	The inflation curve used in the exchange rate calculations.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
RealValue	The number of units of this currency, per unit of currency of the base economy in real terms. Under real-world dynamics, this value is calculated using the exact solution of the stochastic differential equation for Y^t: $$\mathrm{RealValue}(0) = \frac{\mathrm{StartVal}}{\mathrm{Base.StartVal}}$$ and $$\ln(\mathrm{RealValue}(t)) = \ln \widehat{\mathrm{Mu}} + \exp(-\mathrm{Alpha}\ \Delta t)(\ln(\mathrm{RealValue}(t-\Delta t)) - \ln \widehat{\mathrm{Mu}}) - \mathrm{Vol}\ \mathrm{dZ}(t)$$ where $$\widehat{\mathrm{Mu}} := \frac{\mathrm{Mu}}{\mathrm{Base.Mu}}$$ and Base.StartVal and Base.Mu are the values of these parameters for the base economy, and $$\mathrm{Vol} := \begin{cases} \sqrt{\left(\frac{\mathrm{Sigma}^2}{2\mathrm{Alpha}}(1-\exp(-2\mathrm{Alpha}\Delta t))\right)}, & \mathrm{Alpha} \neq 0, \\ 0, & \mathrm{Alpha} = 0 \end{cases}$$ and Sigma:= Volatility.Value.
NominalValue	The number of units, X_t, of this currency per unit of currency of the base economy. Equivalently, the price of one unit of base currency in units of this economy's currency. For more information, see the Scenario Generator Methodology Guide.
NominalReturn	The return over the last time step on a unit of this currency for a base economy investor. Calculated using the formula: $$\mathrm{NominalReturn}(t) = \frac{\mathrm{NominalValue}(t)}{\mathrm{NominalValue}(t-1)} - 1$$
InverseRealValue	The number of units of the base economy's currency per unit of this currency in real terms.
InverseNominalValue	The number of units of the base economy's currency per unit of this currency. Equivalently, the price of one unit of this currency in units of the base currency.
RealValueForEconomy [Economy]	The number of units of the currency of this economy per unit of the currency of the selected Economy in real terms.
NominalValueForEconomy [Economy]	The number of units of the currency of this economy per unit of the currency of the selected Economy.
InverseRealValueForEconomy [Economy]	The number of units of the selected Economy's currency per unit of the currency of this economy in real terms.
InverseNominalValueForEconomy [Economy]	The number of units of the selected Economy's currency per unit of the currency of this economy.

Volatility [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model prescribing the exchange rate process to have a fixed amount of volatility.

Input variables

Name	Description
Value	The fixed volatility of the exchange rate process.

Outputs

Name	Description
Volatility	The volatility of the exchange rate shocks. For the fixed volatility model, this output is the same as the input value.

MarketPriceOfRisk [ConstantMarketPriceOfRisk]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model for constant market price of risk.

Input variables

Name	Description	Conditions
Value	The market price of risk that you want to add in a real world simulation.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

MarketPriceOfRisk [TimeVaryingMarketPriceOfRisk]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model for piecewise constant time-varying market price of risk.

Input variables

Name	Description	Condition
Value	The time-varying market price of risk. Fill the following values: • **Years**—The number of years in the time period. • **MarketPriceOfRisk**—The market price of risk for the time period.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

3.1.6 ExchangeRate [InterestRateParity]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An interest rate parity exchange rate model.

Submodels

Name	Description
Volatility [FixedVolatility]	A model prescribing the exchange rate process to have a fixed amount of volatility.
MarketPriceOfRisk	The market price of risk. This model can be either MarketPriceOfRisk [ConstantMarketPriceOfRisk], or MarketPriceOfRisk [TimeVaryingMarketPriceOfRisk].

Input variables

Name	Description
StartVal	The common initial value of both the nominal and real exchange rates.

Outputs

Name	Description
RealValue	The number of units of this currency per unit of base currency, in real terms. The real exchange rate value is derived from the nominal exchange rate value as follows: $\mathrm{RealValue}(t) = \mathrm{NominalValue}(t)\dfrac{\mathrm{Base.Inflation.Index}(t)}{\mathrm{Inflation.Index}(t)}$ where Base.Inflation.Index is the inflation index of the base economy.
NominalValue	The number of units of this currency per unit of base currency, or, the price of one unit of base currency in units of this currency.
NominalReturn	The return over the last time step on a unit of this currency for a base economy investor. Calculated using the formula: $\mathrm{NominalReturn}(t) = \dfrac{\mathrm{NominalValue}(t)}{\mathrm{NominalValue}(t-1)} - 1$

Name	Description
InverseRealValue	The number of units of base currency per unit of this currency, in real terms.
InverseNominalValue	The number of units of base currency per unit of this currency, or, the price of one unit of this currency in units of the base currency.
RealValueForEconomy [Economy]	The number of units of the currency of this economy, per unit of the currency of the economy that you select, in real terms.
NominalValueForEconomy [Economy]	The number of units of the currency of this economy, per unit of the currency of the economy that you select.
InverseRealValueForEconomy [Economy]	The number of units of the currency of the economy that you select, per unit of this economy, in real terms.
InverseNominalValueForEconomy [Economy]	The number of units of the currency of the economy that you select, per unit of this economy.

Volatility [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model prescribing the exchange rate process to have a fixed amount of volatility.

Input variables

Name	Description
Value	The fixed volatility of the exchange rate process.

Outputs

Name	Description
Volatility	The volatility of the exchange rate shocks. For the fixed volatility model, this output is the same as the input value.

MarketPriceOfRisk [ConstantMarketPriceOfRisk]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model for constant market price of risk.

Input variables

Name	Description	Conditions
Value	The market price of risk that you want to add in a real world simulation.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

MarketPriceOfRisk [TimeVaryingMarketPriceOfRisk]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A model for piecewise constant time-varying market price of risk.

Input variables

Name	Description	Condition
Value	The time-varying market price of risk. Fill the following values: • **Years**—The number of years in the time period. • **MarketPriceOfRisk**—The market price of risk for the time period.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

3.1.7 CreditModels

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The Scenario Generator software supports multiple credit models, as well as credit models (called municipal spreads) that are adapted for municipal bond modeling. There is always one primary credit model in every economy, but there can be any number of added credit models. In addition, there can be any number of municipal spread models, and all are housed in the CreditModels container.

For more information about credit modeling in the Scenario Generator software, see the Credit Models methodology.

Submodels

Name	Description
CreditModel	This model is the primary model for credit rating transitions and is used in the pricing of credit-risky bonds and determination of credit spreads. You can change this model to any of the following variants: • CreditModelG2, CreditModelG2FlexiClass

Name	Description
	• CreditModelG2X • CreditModelG3 • CreditModelG2Factor • CreditModelG3Factor • CreditModelHybrid • DummyCreditModel Use the dummy credit model only if your license does not allow simulations of credit risk (ESG and RSG) • G2CreditStatisticalSpreadModel (RSG)

Addable submodels

Name	Description	Availability
CreditModelG2, CreditModelG2FlexiClass	Models changes in credit rating by simulating credit transitions from a baseline credit transition matrix, and models spreads by a stochastic risk premium.	
CreditModelG2X	Use a set of credit spread factor exposures to scale the G2 credit spreads.	
CreditModelG3	A default-only model of stochastic spreads and market-consistent default events for credit-risky debt instruments.	
CreditModelG2Factor	Models credit transitions and spreads based on an input transition probability matrix. Real-world and risk-neutral transition probabilities also have a stochastic component, which is driven by systematic and specific credit factors.	
CreditModelG3Factor	A default-only credit model which is driven by systematic and specific credit factors.	
CreditModelHybrid	A factor-based hybrid credit model which decouples real-world transitions from risk-neutral transitions.	
MunicipalSpread	Municipal spread models facilitate the modification of a credit model to account for tax benefits.	
G2CreditStatisticalSpreadModel	A variation of the CreditModelG2, which models migrations between non-default credit states based on the underlying transition matrix, and models spread distributions based on risk drivers that you specify.	RSG

CreditModelG2, CreditModelG2FlexiClass

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models changes in credit rating by simulating credit transitions from a baseline credit transition matrix. The initial transition matrix is evolved over time via the stochastic credit driver. The model is used to simulate risky assets.

Note CreditModelG2FlexiClass uses the classes specified in the CreditClasses parameter set on the Simulation node. This model is ONLY available as an additional credit model.

For more information about credit modeling in the Scenario Generator software, see the Credit Models methodology.

Submodels

Name	Description
CreditStochasticDriver	A stochastic process that drives the changes in credit transitions. This driver can be one of the following models: • CreditStochasticDriver [ExtendedOneFactorCIR]—uses a Brownian bridge • CreditStochasticDriver [OneFactorCIR] • CreditStochasticDriver [SingleTermPremiumCIRTD]—time-dependent • CreditStochasticDriver [DualTermPremiumCIRTD]—time-dependent

Input variables

Name	Description
RecoveryRate	The proportion of promised cash flows recovered in the event of default for each specified seniority.
RealWorldBaseCreditTransitionMatrix	Defines the probabilities of a bond changing credit rating over one year. The application uses this matrix to construct a baseline generator matrix, containing transition intensities.
RiskNeutralBaselineScalingFactor	These scaling parameters are applied to the baseline generator matrix to derive the baseline risk-neutral generator matrix.
RealWorldScalingParameters	These parameters specify the linear transformation on the baseline generator matrix to the stochastic real-world generator matrix. C[0] is the constant term and C[1] is the coefficient of the stochastic term.
RiskNeutralScalingParameters	These parameters specify the linear transformation on the baseline generator matrix to the stochastic risk-neutral generator matrix. C[0] is the constant term and C[1] is the coefficient of the stochastic term.
NumberOfSubdivisions	The number of subdivisions of each time step for Brownian bridge submodels.
DeterministicRecalibrationCreditClass	The credit class that the application uses for deterministic recalibration.
DeterministicRecalibrationTerm	The term, in years, that the application uses for deterministic recalibration.
DeterministicRecalibrationPiLowerBound	The lower bound for the initial value of the credit stochastic driver (StartVal) in a deterministic recalibration.
DeterministicRecalibrationPiUpperBound	The upper bound for the initial value of the credit stochastic driver (StartVal) in a deterministic recalibration.

Outputs

Name	Description
DefaultIntensity [CreditClass]	The default intensity for the specified credit class.
RiskNeutralDefaultIntensity [CreditClass]	The risk-neutral default intensity for the specified credit class.
DefaultProbability [CreditClass, Maturity]	The default probability for the specified credit class and maturity over the time step. The default probability is stochastic if the scaling parameter C[1] is non-zero. For more information about the credit model, see the *Scenario Generator Methodology Guide*.
RiskNeutralDefaultProbability [CreditClass, Maturity]	The risk-neutral default probability for the specified credit class and maturity over the time step. The default probability is stochastic if the scaling parameter C[1] is non-zero. For more information about the credit model, see the *Scenario Generator Methodology Guide*.

Name	Description
SpotSpread [CreditClass, Maturity, Seniority]	The spot spread for the specified credit class, maturity, and seniority.
FundamentalSpread [CreditClass, Maturity, Seniority]	The fundamental spread for the specified credit class, maturity, and seniority. This is the part of the spread which is required to compensate for losses due to defaults, accounting for the possibility of rating transitions (and assuming that the associated equity ZScoreMPR is zero). This output is only supported for real world simulations if the stochastic credit driver is using a zero market price of risk.
CDSSpread [Frequency, CreditClass, Maturity]	The total spread or premium a buyer of a credit default swap (CDS) contract must pay per year, while the contract is active. If the bond issuer defaults, the seller of the contract undertakes to pay bondholder losses to the CDS holder. This output is calculated using the formula $$\mathrm{CDSSpread}(f, C, \tau) = f \times (1 - \delta(S)) \frac{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)\left(Q\left(C, \frac{n-1}{f}\right) - Q\left(C, \frac{n}{f}\right)\right)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right) Q\left(C, \frac{n}{f}\right)}$$ where: • *f* is the frequency. • *C* is the credit class. • τ is the maturity. • *S* is the default seniority. • $Z(C, \tau, S)$ is the zero coupon bond price (with credit class *C*, maturity τ and seniority *S*, based on this credit model and the primary nominal yield curve for this economy). • $Q(C, \tau)$ is the survival probability for the credit class *C* to maturity τ. When the maturity τ is not an integer multiple of $\frac{1}{f}$, the output returns 0.0.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, C, \tau, S) = f \frac{1 - Z(C, \tau, S)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)}$$ where: • *f* is the frequency. • *C* is the credit class. • τ is the maturity. • *S* is the seniority. • $Z(C, \tau, S)$ is the zero coupon bond price (with credit class *C*, maturity τ and seniority *S*) based on this nominal yield curve and the primary credit model for this economy.
ParYieldSpread [Frequency, CreditClass, Maturity, Seniority]	The application calculates the par yield spread as the difference between the credit-risky par yield and the risk-free par yield for the default nominal yield curve.
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from StartCreditClass to EndCreditClass over the time step. The transition probability is stochastic if the scaling parameter C[1] is non-zero. For more information about the credit model, see the *Scenario Generator Methodology Guide*.
ConditionalTransitionProbability [InterestRateModel, EquityAsset, StartCreditClass, EndCreditClass]	The probability of transitioning from StartCreditClass to EndCreditClass over the time step, conditional on the decorrelated Zscore shock from the associated EquityAsset. The ZScore shock is decorrelated from the selected InterestRateModel shock.

Analysis tests

Name	Description
Initial Credit Spread Curve	Enables you to output the annually compounded multiplicative spot spreads as at time zero for a defined credit class, seniority, and set number of maturities.
Bond Market Instrument Test	Prices the bonds that you define, at time zero. Also calculates the annually compounded bond yields. **Note** If you enter multiple bonds, each appears as a separate line in the **Selected** list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

CreditStochasticDriver [OneFactorCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. This implementation uses a simple Cox-Ingersoll-Ross (CIR) model.

Input variables

Name	Description
Alpha	The rate of mean reversion of the stochastic credit driver.
Sigma	The volatility of the stochastic credit driver.
Mu	The mean of the stochastic credit driver.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The stochastic credit driver value.

CreditStochasticDriver [ExtendedOneFactorCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. This implementation uses a Cox-Ingersoll-Ross (CIR) model that has been extended to incorporate a Brownian bridge algorithm to model the finer details of the stochastic path at several subdivisions of each simulation time step. The number of subdivisions used is an input to the credit model to which the CreditStochasticDriver belongs.

Input variables

Name	Description
Alpha	The rate of mean reversion of the stochastic credit driver.
Sigma	The volatility of the stochastic credit driver.
Mu	The mean of the stochastic credit driver.
StartVal	The initial value of the stochastic credit driver.
MarketPriceOfRisk	The market price of risk for the stochastic credit driver. Used for real world simulations only.

Outputs

Name	Description
Value	The stochastic credit driver value at this time step.
IntegratedValue	The average value of the stochastic credit driver over the time step, taking into account the path over the Brownian bridge subdivisions.

CreditStochasticDriver [SingleTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	Enter the following parameters for each time period: • **Years**—The length of the time period. • **Alpha**—The rate of mean reversion of the stochastic credit driver. • **Mu**—The mean of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver. • **MarketPriceOfRisk**—The market price of risk for the stochastic credit driver. Used for real world simulations only.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

CreditStochasticDriver [DualTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	The time-varying parameters of the stochastic process. Fill the following fields for each time period: • **Years**—The number of years in the time period. • **RiskNeutralAlpha**—The risk-neutral rate of mean reversion of the stochastic credit driver. • **RiskNeutralMu**—The risk-neutral mean reversion level of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver. • **RealWorldAlpha**—The real-world rate of mean reversion of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**. • **RealWorldMu**—The real-world mean reversion level of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

CreditModelG2X

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models changes in credit rating by simulating credit transitions from a baseline credit transition matrix. The initial transition matrix is evolved over time via the stochastic credit driver. Credit spreads are derived from a set of exposures to the stochastic driver. The model is used to simulate risky assets.

For more information about credit modeling in the Scenario Generator software, see the Credit Models methodology.

Submodels

Name	Description
CreditStochasticDriver	A stochastic process that drives the changes in credit transitions. This driver can be either the CreditStochasticDriver [ExtendedOneFactorCIR] model that uses a Brownian bridge, or the CreditStochasticDriver [OneFactorCIR] model.

Input variables

Name	Description
RecoveryRate	The proportion of promised cash flows recovered in the event of default for each specified seniority.
RealWorldBaseCreditTransitionMatrix	Defines the probabilities of a bond changing credit rating over one year. The application uses this matrix to construct a baseline generator matrix, containing transition intensities.
RiskNeutralBaselineScalingFactor	These scaling parameters are applied to the baseline generator matrix to derive the baseline risk-neutral generator matrix.
RealWorldScalingParameters	These parameters specify the linear transformation on the baseline generator matrix to the stochastic real-world generator matrix. C[0] is the constant term and C[1] is the coefficient of the stochastic term.
RiskNeutralScalingParameters	These parameters specify the linear transformation on the baseline generator matrix to the stochastic risk-neutral generator matrix. C[0] is the constant term and C[1] is the coefficient of the stochastic term.
NumberOfSubdivisions	The number of subdivisions of each time step for Brownian bridge submodels.
StochasticDriverLoadings	The strength of exposure of credit spreads to the stochastic credit driver.
InterpolateLoadings	To use linear interpolation of loadings between terms, select **True**. To round the loading down to the nearest term instead, select **False**.
DeterministicRecalibrationCreditClass	The credit class that the application uses for deterministic recalibration.
DeterministicRecalibrationTerm	The term, in years, that the application uses for deterministic recalibration.

Outputs

Name	Description
DefaultIntensity [CreditClass]	The default intensity for the specified credit class.
RiskNeutralDefaultIntensity [CreditClass]	The risk-neutral default intensity for the specified credit class.
DefaultProbability [CreditClass, Maturity]	The default probability for the specified credit class and maturity.
RiskNeutralDefaultProbability [CreditClass, Maturity]	The risk-neutral default probability for the specified credit class and maturity.

Name	Description
SpotSpread [CreditClass, Maturity, Seniority]	The spot spread for the specified credit class, maturity, and seniority. Calculated using the formula: $$\begin{aligned}&\text{SpotSpread}_{\text{G2X}}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)\\&\quad = \text{SpotSpread}_{\text{G2}}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t)\\&\quad \times \text{StochasticDriverLoading}(\text{CreditClass}, \text{Maturity})\end{aligned}$$
FundamentalSpread [CreditClass, Maturity, Seniority]	The fundamental spread for the specified credit class, maturity, and seniority. This is the part of the spread which is required to compensate for losses due to defaults, accounting for the possibility of rating transitions (and assuming that the associated equity ZScoreMPR is zero). This output is only supported for real world simulations if the stochastic credit driver is using a zero market price of risk.
CDSSpread [Frequency, CreditClass, Maturity]	The total spread or premium a buyer of a credit default swap (CDS) contract must pay per year, while the contract is active. If the bond issuer defaults, the seller of the contract undertakes to pay bondholder losses to the CDS holder. This output is calculated using the formula $$\begin{aligned}&\text{CDSSpread}(f, C, \tau)\\&\quad = f \times (1-\delta(S))\frac{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)\left(Q\left(C, \frac{n-1}{f}\right) - Q\left(C, \frac{n}{f}\right)\right)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right) Q\left(C, \frac{n}{f}\right)}\end{aligned}$$ where: • f is the frequency. • C is the credit class. • τ is the maturity. • S is the default seniority. • $Z(C, \tau, S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S, based on this credit model and the primary nominal yield curve for this economy) • $Q(C, \tau)$ is the survival probability for the credit class C to maturity τ. When the maturity τ is not an integer multiple of $\frac{1}{f}$, the output returns 0.0.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\text{ParYield}(f, C, \tau, S) = f\frac{1 - Z(C, \tau, S)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)}$$ where: • f is the frequency. • C is the credit class. • τ is the maturity. • S is the seniority. • $Z(C, \tau, S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S) based on this nominal yield curve and the primary credit model for this economy.
ParYieldSpread [Frequency, CreditClass, Maturity, Seniority]	The application calculates the par yield spread as the difference between the credit-risky par yield and the risk-free par yield for the default nominal yield curve.
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another.

Name	Description
ConditionalTransitionProbability [InterestRateModel, EquityAsset, StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another over the previous time step, conditional on the selected equity ZScore shock, which is decorrelated with the selected yield curve shocks.

Analysis tests

Name	Description
Initial Credit Spread Curve	Allows you to output the annually compounded multiplicative spot spreads as at time zero for a defined credit class, seniority, and set number of maturities.
Bond Market Instrument Test	Prices the bonds that you define, at time zero. Also calculates the annually compounded bond yields. **Note** If you enter multiple bonds, each appears as a separate line in the **Selected** list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

CreditStochasticDriver [OneFactorCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. This implementation uses a simple Cox-Ingersoll-Ross (CIR) model.

Input variables

Name	Description
Alpha	The rate of mean reversion of the stochastic credit driver.
Sigma	The volatility of the stochastic credit driver.
Mu	The mean of the stochastic credit driver.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The stochastic credit driver value.

CreditStochasticDriver [ExtendedOneFactorCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. This implementation uses a Cox-Ingersoll-Ross (CIR) model that has been extended to incorporate a Brownian bridge algorithm to model the finer details of the stochastic path at several subdivisions of each simulation time step. The number of subdivisions used is an input to the credit model to which the CreditStochasticDriver belongs.

Input variables

Name	Description
Alpha	The rate of mean reversion of the stochastic credit driver.
Sigma	The volatility of the stochastic credit driver.
Mu	The mean of the stochastic credit driver.
StartVal	The initial value of the stochastic credit driver.
MarketPriceOfRisk	The market price of risk for the stochastic credit driver. Used for real world simulations only.

Outputs

Name	Description
Value	The stochastic credit driver value at this time step.
IntegratedValue	The average value of the stochastic credit driver over the time step, taking into account the path over the Brownian bridge subdivisions.

CreditModelG3

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A default-only model of stochastic spreads and default events for credit-risky debt instruments. For each credit class, risk-neutral default intensities or "hazard rates" are decomposed into a sum of ExcessHazardRate processes.

For more information about credit modeling in the Scenario Generator software, see the Credit Models methodology.

Submodels

Name	Description
ExcessHazardRates	A container for the excess hazard rate processes corresponding to each credit class.

Input variables

Name	Description
RecoveryRate	The proportion of promised cash flows recovered in the event of default for each specified seniority.
DeterministicRecalibrationTerm	The term, in years, that the application uses for deterministic recalibration.

Outputs

Name	Description
DefaultIntensity [CreditClass]	The default intensity for the specified credit class.
RiskNeutralDefaultIntensity [CreditClass]	The risk-neutral default intensity for the specified credit class.
DefaultProbability [CreditClass, Maturity]	The default probability for the specified credit class and maturity.
RiskNeutralDefaultProbability [CreditClass, Maturity]	The risk-neutral default probability for the specified credit class and maturity.
SpotSpread [CreditClass, Maturity, Seniority]	The spot spread for the specified credit class, maturity, and seniority.
CDSSpread [Frequency, CreditClass, Maturity]	The total spread or premium a buyer of a credit default swap (CDS) contract must pay per year, while the contract is active. If the bond issuer defaults, the seller of the contract undertakes to pay bondholder losses to the CDS holder. This output is calculated using the formula $\mathrm{CDSSpread}(f,C,\tau) = f\times(1-\delta(S))\dfrac{\sum_{n=1}^{f\times\tau} Z\left(C,\frac{n}{f},S\right)\left(Q\left(C,\frac{n-1}{f}\right)-Q\left(C,\frac{n}{f}\right)\right)}{\sum_{n=1}^{f\times\tau} Z\left(C,\frac{n}{f},S\right)Q\left(C,\frac{n}{f}\right)}$ where: • *f* is the frequency. • *C* is the credit class. • τ is the maturity. • *S* is the default seniority. • $Z(C,\tau,S)$ is the zero coupon bond price (with credit class *C*, maturity τ and seniority *S*, based on this credit model and the primary nominal yield curve for this economy). • $Q(C,\tau)$ is the survival probability for the credit class *C* to maturity τ. When the maturity τ is not an integer multiple of $\frac{1}{f}$, the output returns 0.0.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $\mathrm{ParYield}(f,C,\tau,S) = f\dfrac{1-Z(C,\tau,S)}{\sum_{n=1}^{f\times\tau} Z\left(C,\frac{n}{f},S\right)}$ where: • *f* is the frequency. • *C* is the credit class.

Name	Description
	• τ is the maturity. • S is the seniority. • $Z(C, \tau, S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S) based on this nominal yield curve and the primary credit model for this economy.
ParYieldSpread [Frequency, CreditClass, Maturity, Seniority]	The application calculates the par yield spread as the difference between the credit-risky par yield and the risk-free par yield for the default nominal yield curve.
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another.
ConditionalTransitionProbability [InterestRateModel, EquityAsset, StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another over the previous time step, conditional on the selected equity ZScore shock, which is decorrelated with the selected yield curve shocks.

Analysis tests

Name	Description
Initial Credit Spread Curve	Allows you to output the annually compounded multiplicative spot spreads as at time zero for a defined credit class, seniority, and set number of maturities.
Bond Market Instrument Test	Prices the bonds that you define, at time zero. Also calculates the annually compounded bond yields. **Note** If you enter multiple bonds, each appears as a separate line in the **Selected** list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

ExcessHazardRates

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A container for the excess hazard rate processes used by the G3 credit model.

Submodels

Name	Description
HazardRateOneFactorCIR	The excess hazard rate submodels AAA, AA, A, BBB, BB, B, CCC are Cox-Ingersoll-Ross processes representing the increased likelihood of default for each successively lower credit quality.

Input variables

Name	Description
NumberOfSubdivisions	The number of subdivisions of each time step for Brownian bridge submodels.

Outputs

Name	Description
HazardRate [CreditClass]	The instantaneous hazard rate (default intensity) for the specified credit class. The hazard rate is obtained by summing excess hazard rates corresponding to credit classes at and above the specified credit class.

AAA to CCC [HazardRateOneFactorCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The HazardRateOneFactorCIR models (AAA, AA, A, BBB, BB, B, and CCC) represent risk-neutral excess hazard rate processes. These processes drive the stochastic variations in spreads for the G3 credit model.

Each process models the increased likelihood of default for each successively lower credit quality. *For example*, the BBB excess hazard rate represents the increased risk-neutral default intensity of BBB-rated bonds above A-rated bonds. The AAA 'excess' hazard rate simply represents the risk-neutral default intensity of AAA-rated bonds.

The evolution of the excess hazard rate processes uses an implementation of the Cox-Ingersoll-Ross (CIR) model that incorporates a Brownian bridge algorithm. The number of subdivisions used in the Brownian bridge is an input to the ExcessHazardRates container.

Input variables

Name	Description
StartVal	The initial value of the stochastic credit driver parameter.
Mu	The mean reversion level of the stochastic credit driver.
RiskNeutralMu	The risk-neutral mean reversion level of the stochastic credit driver. Only required if you have set **UseRiskNeutralValuation** to **False** at the simulation level.
Alpha	The rate of mean reversion of the stochastic credit driver parameter.
RiskNeutralAlpha	The risk-neutral rate of mean reversion of the stochastic credit driver parameter. Only required if you have set **UseRiskNeutralValuation** to **False** at the simulation level.
Sigma	The volatility of the stochastic credit driver parameter.

Outputs

Name	Description
Value	The value of the excess hazard rate at this time step.
IntegratedValue	The average value of the stochastic credit driver over the time step, taking into account the path over the Brownian bridge subdivisions.

CreditModelG2Factor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The G2 Factor credit model is a factor-based version of the CreditModelG2, CreditModelG2FlexiClass model that blends systematic risk with independent specific risk to achieve risk factor correlations.

Submodels

Name	Description
Driver1–Driver7	Models that drive the changes in credit transitions. The possible model types for each driver are the following: • Driver1 to Driver7 [SingleTermPremiumCIR] • Driver1 to Driver7 [DualTermPremiumCIR] • Driver1 to Driver7 [SingleTermPremiumCIRTD] • Driver1 to Driver7 [DualTermPremiumCIRTD]

Input variables

Name	Description
RecoveryRate	The proportion of promised cash flows recovered in the event of default for each specified seniority.
BaseTransitionProbabilityMatrix	Defines the probabilities of a bond changing credit rating over one year. This matrix is used to construct a baseline generator matrix.
RiskNeutralBaselineScalingFactor	These scaling parameters are applied to the baseline generator matrix to derive the baseline risk-neutral generator matrix.
RealWorldLoadingFactors	These parameters specify the transformation on the baseline generator matrix to the stochastic real-world generator matrix. C[0] is the constant term and C[1] to C[7] are the coefficients of the stochastic drivers.
RiskNeutralLoadingFactors	These parameters specify the transformation on the baseline risk-neutral generator matrix to the stochastic risk-neutral generator matrix. C[0] is the constant term and C[1] to C[7] are the coefficients of the stochastic drivers.

Outputs

Name	Description
DefaultIntensity [CreditClass]	The default intensity for the specified credit class.
RiskNeutralDefaultIntensity [CreditClass]	The risk-neutral default intensity for the specified credit class.
DefaultProbability [CreditClass, Maturity]	The default probability for the specified credit class and maturity.
RiskNeutralDefaultProbability [CreditClass, Maturity]	The risk-neutral default probability for the specified credit class and maturity.

Name	Description
SpotSpread [CreditClass, Maturity, Seniority]	The spot spread for the specified credit class, maturity, and seniority.
FundamentalSpread [CreditClass, Maturity, Seniority]	The fundamental spread for the specified credit class, maturity, and seniority. This is the part of the spread which is required to compensate for losses due to defaults, taking into account the possibility of rating transitions (and assuming that the associated equity ZScoreMPR is zero). This output is only supported for real world simulations if all the stochastic credit drivers of type SingleTermPremiumCIR or SingleTermPremiumCIRTD are using a zero market price of risk.
CDSSpread [Frequency, CreditClass, Maturity]	The total spread or premium a buyer of a credit default swap (CDS) contract must pay per year, while the contract is active. If the bond issuer defaults, the seller of the contract undertakes to pay bondholder losses to the CDS holder. This output is calculated using the formula $\mathrm{CDSSpread}(f,C,\tau) = f \times (1-\delta(S)) \frac{\sum_{n=1}^{f\times\tau} Z\left(C,\frac{n}{f},S\right)\left(Q\left(C,\frac{n-1}{f}\right)-Q\left(C,\frac{n}{f}\right)\right)}{\sum_{n=1}^{f\times\tau} Z\left(C,\frac{n}{f},S\right)Q\left(C,\frac{n}{f}\right)}$ where: • f is the frequency. • C is the credit class. • τ is the maturity. • S is the default seniority. • $Z(C,\tau,S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S, based on this credit model and the primary nominal yield curve for this economy). • $Q(C,\tau)$ is the survival probability for the credit class C to maturity τ. When the maturity τ is not an integer multiple of $\frac{1}{f}$, the output returns 0.0.
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $\mathrm{ParYield}(f,C,\tau,S) = f\frac{1-Z(C,\tau,S)}{\sum_{n=1}^{f\times\tau} Z\left(C,\frac{n}{f},S\right)}$ where: • f is the frequency. • C is the credit class. • τ is the maturity. • S is the seniority. • $Z(C,\tau,S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S) based on this nominal yield curve and the primary credit model for this economy.
ParYieldSpread [Frequency, CreditClass, Maturity, Seniority]	The application calculates the par yield spread as the difference between the credit-risky par yield and the risk-free par yield for the default nominal yield curve.
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another.
ConditionalTransitionProbability [InterestRateModel, EquityAsset, StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another over the previous time step, conditional on the selected equity ZScore shock, which is decorrelated with the selected yield curve shocks.

Analysis tests

Name	Description
Initial Credit Spread Curve	Allows you to output the annually compounded multiplicative spot spreads as at time zero for a defined credit class, seniority, and set number of maturities.
Bond Market Instrument Test	Prices the bonds that you define, at time zero. Also calculates the annually compounded bond yields. **Note** If you enter multiple bonds, each appears as a separate line in the **Selected** list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

Driver1 to Driver7 [SingleTermPremiumCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model.

Input variables

Name	Description	Conditions
Alpha	The mean reversion rate of the stochastic credit driver.	
Sigma	The volatility of the stochastic credit driver.	
Mu	The mean reversion level of the stochastic credit driver.	
StartVal	The initial value of the stochastic credit driver.	
SystematicComponent	The correlation between the credit driver shock and the systematic credit shock.	
MarketPriceOfRisk	The market price of risk.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [DualTermPremiumCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model.

Input variables

Name	Description	Conditions
StartVal	The initial value of the stochastic credit driver.	
RealWorldMu	The real-world mean reversion level of the stochastic credit driver.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMu	The risk-neutral mean reversion level of the stochastic credit driver.	
RealWorldAlpha	The real-world rate of mean reversion of the stochastic credit driver.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralAlpha	The risk-neutral rate of mean reversion of the stochastic credit driver.	
Sigma	The volatility of the stochastic credit driver.	
SystematicComponent	The correlation between the credit driver shock and the systematic credit shock.	

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [SingleTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	Enter the following parameters for each time period: • **Years**—The length of the time period. • **Alpha**—The rate of mean reversion of the stochastic credit driver. • **Mu**—The mean of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver. • **MarketPriceOfRisk**—The market price of risk for the stochastic credit driver. Used for real world simulations only.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [DualTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	The time-varying parameters of the stochastic process. Fill the following fields for each time period: • **Years**—The number of years in the time period. • **RiskNeutralAlpha**—The risk-neutral rate of mean reversion of the stochastic credit driver. • **RiskNeutralMu**—The risk-neutral mean reversion level of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver. • **RealWorldAlpha**—The real-world rate of mean reversion of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**. • **RealWorldMu**—The real-world mean reversion level of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

CreditModelG3Factor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The G3 Factor credit model is a factor-based version of the CreditModelG3 model that blends systematic risk with independent specific risk to achieve risk factor correlations.

Submodels

Name	Description
Driver1–Driver7	Models that drive the changes in credit transitions. The possible model types for each driver are the following: • Driver1 to Driver7 [SingleTermPremiumCIR] • Driver1 to Driver7 [DualTermPremiumCIR] • Driver1 to Driver7 [SingleTermPremiumCIRTD] • Driver1 to Driver7 [DualTermPremiumCIRTD]

Input variables

Name	Description	Conditions
RecoveryRate	The proportion of promised cash flows recovered in the event of default for each specified seniority.	
RealWorldScalingParameters	Defines the scaling parameters for the real-world default intensities.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
LoadingFactors	Loading factors that the application uses in the calculation of the default intensity from the stochastic drivers.	

Outputs

Name	Description
AverageDefaultIntensity [CreditClass]	The default intensity averaged over the time step for the specified credit class.
DefaultIntensity [CreditClass]	The default intensity for the specified credit class.

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td>RiskNeutralDefaultIntensity [CreditClass]</td><td>The risk-neutral default intensity for the specified credit class.</td></tr>
<tr><td>DefaultProbability [CreditClass, Maturity]</td><td>The default probability for the specified credit class and maturity.</td></tr>
<tr><td>RiskNeutralDefaultProbability [CreditClass, Maturity]</td><td>The risk-neutral default probability for the specified credit class and maturity.</td></tr>
<tr><td>SpotSpread [CreditClass, Maturity, Seniority]</td><td>The spot spread for the specified credit class, maturity, and seniority.</td></tr>
<tr><td>FundamentalSpread [CreditClass, Maturity, Seniority]</td><td>The fundamental spread for the specified credit class, maturity, and seniority. This is the part of the spread which is required to compensate for losses due to defaults, taking into account the possibility of rating transitions (and assuming that the associated equity ZScoreMPR is zero). This output is only supported for real-world simulations if all the stochastic credit drivers of type SingleTermPremiumCIR or SingleTermPremiumCIRTD are using a zero market price of risk.</td></tr>
<tr><td>CDSSpread [Frequency, CreditClass, Maturity]</td><td>The total spread or premium a buyer of a credit default swap (CDS) contract must pay per year, while the contract is active. If the bond issuer defaults, the seller of the contract undertakes to pay bondholder losses to the CDS holder. This output is calculated using the formula

$$\mathrm{CDSSpread}(f, C, \tau) = f \times (1 - \delta(S)) \frac{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)\left(Q\left(C, \frac{n-1}{f}\right) - Q\left(C, \frac{n}{f}\right)\right)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right) Q\left(C, \frac{n}{f}\right)}$$

where:
• f is the frequency.
• C is the credit class.
• τ is the maturity.
• S is the default seniority.
• $Z(C, \tau, S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S, based on this credit model and the primary nominal yield curve for this economy).
• $Q(C, \tau)$ is the survival probability for the credit class C to maturity τ.
When the maturity τ is not an integer multiple of $\frac{1}{f}$, the output returns 0.0.</td></tr>
<tr><td>ParYield [Frequency, CreditClass, Maturity, Seniority]</td><td>The par yield at the specified maturity, with the number of payments per annum specified by the Frequency parameter. For example, for semiannual par yields set Frequency = 2. This output is calculated using the formula

$$\mathrm{ParYield}(f, C, \tau, S) = f \frac{1 - Z(C, \tau, S)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)}$$

where:
• f is the frequency.
• C is the credit class.
• τ is the maturity.
• S is the seniority.
• $Z(C, \tau, S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S) based on this nominal yield curve and the primary credit model for this economy.</td></tr>
<tr><td>ParYieldSpread [Frequency, CreditClass, Maturity, Seniority]</td><td>The application calculates the par yield spread as the difference between the credit-risky par yield and the risk-free par yield for the default nominal yield curve.</td></tr>
</table>

Name	Description
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another.
ConditionalTransitionProbability [InterestRateModel, EquityAsset, StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another over the previous time step, conditional on the selected equity ZScore shock, which is decorrelated with the selected yield curve shocks.

Analysis tests

Name	Description
Initial Credit Spread Curve	Allows you to output the annually compounded multiplicative spot spreads as at time zero for a defined credit class, seniority, and set number of maturities.
Bond Market Instrument Test	Prices the bonds that you define, at time zero. Also calculates the annually compounded bond yields. **Note** If you enter multiple bonds, each appears as a separate line in the **Selected** list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

Driver1 to Driver7 [SingleTermPremiumCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model.

Input variables

Name	Description	Conditions
Alpha	The mean reversion rate of the stochastic credit driver.	
Sigma	The volatility of the stochastic credit driver.	
Mu	The mean reversion level of the stochastic credit driver.	
StartVal	The initial value of the stochastic credit driver.	
SystematicComponent	The correlation between the credit driver shock and the systematic credit shock.	
MarketPriceOfRisk	The market price of risk.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [DualTermPremiumCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model.

Input variables

Name	Description	Conditions
StartVal	The initial value of the stochastic credit driver.	
RealWorldMu	The real-world mean reversion level of the stochastic credit driver.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMu	The risk-neutral mean reversion level of the stochastic credit driver.	
RealWorldAlpha	The real-world rate of mean reversion of the stochastic credit driver.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralAlpha	The risk-neutral rate of mean reversion of the stochastic credit driver.	
Sigma	The volatility of the stochastic credit driver.	
SystematicComponent	The correlation between the credit driver shock and the systematic credit shock.	

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [SingleTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	Enter the following parameters for each time period: • **Years**—The length of the time period. • **Alpha**—The rate of mean reversion of the stochastic credit driver. • **Mu**—The mean of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver. • **MarketPriceOfRisk**—The market price of risk for the stochastic credit driver. Used for real world simulations only.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [DualTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	The time-varying parameters of the stochastic process. Fill the following fields for each time period: • **Years**—The number of years in the time period. • **RiskNeutralAlpha**—The risk-neutral rate of mean reversion of the stochastic credit driver. • **RiskNeutralMu**—The risk-neutral mean reversion level of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver.

Name	Description
	• **RealWorldAlpha**—The real-world rate of mean reversion of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**. • **RealWorldMu**—The real-world mean reversion level of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

CreditModelHybrid

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The CreditModelHybrid is a factor-based hybrid credit model, which decouples real-world transitions from risk-neutral transitions.

Submodels

Name	Description
RealWorldDynamics	Used to model real-world credit transitions in bond portfolios. The possible values are the following: • RealWorldDynamics [G2Dynamics] • RealWorldDynamics [G3Dynamics]
RiskNeutralDynamics	Used to model risk-neutral credit transition bond portfolios, and spread risk. The possible values are the following: • RiskNeutralDynamics [G2Dynamics] • RiskNeutralDynamics[G3Dynamics]
Driver1–Driver7	Models that drive the changes in credit transitions. The possible values for each model are the following: • Driver1 to Driver7 [SingleTermPremiumCIR] • Driver1 to Driver7 [DualTermPremiumCIR] • Driver1 to Driver7 [SingleTermPremiumCIRTD] • Driver1 to Driver7 [DualTermPremiumCIRTD]

Input variables

Name	Description
RecoveryRate	The proportion of promised cash flows recovered in the event of default for each specified seniority.

Outputs

Name	Description
DefaultIntensity [CreditClass]	The default intensity for the specified credit class.
RiskNeutralDefaultIntensity [CreditClass]	The risk-neutral default intensity for the specified credit class.
DefaultProbability [CreditClass, Maturity]	The default probability for the specified credit class and maturity.
RiskNeutralDefaultProbability [CreditClass, Maturity]	The risk-neutral default probability for the specified credit class and maturity.
SpotSpread [CreditClass, Maturity, Seniority]	The spot spread for the specified credit class, maturity, and seniority.
FundamentalSpread [CreditClass, Maturity, Seniority]	The fundamental spread for the specified credit class, maturity, and seniority. This is the part of the spread which is required to compensate for losses due to defaults, taking into account the possibility of rating transitions (and assuming that the associated equity ZScoreMPR is zero). This output is only supported for real-world simulations if all the stochastic credit drivers of type SingleTermPremiumCIR or SingleTermPremiumCIRTD are using a zero market price of risk.
CDSSpread [Frequency, CreditClass, Maturity]	The total spread or premium a buyer of a credit default swap (CDS) contract must pay per year, while the contract is active. If the bond issuer defaults, the seller of the contract undertakes to pay bondholder losses to the CDS holder. This output is calculated using the formula $$\mathrm{CDSSpread}(f, C, \tau) = f \times (1-\delta(S)) \frac{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)\left(Q\left(C, \frac{n-1}{f}\right) - Q\left(C, \frac{n}{f}\right)\right)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right) Q\left(C, \frac{n}{f}\right)}$$ where: • f is the frequency. • C is the credit class. • τ is the maturity. • S is the default seniority. • $Z(C, \tau, S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S, based on this credit model and the primary nominal yield curve for this economy). • $Q(C, \tau)$ is the survival probability for the credit class C to maturity τ. When the maturity τ is not an integer multiple of $\frac{1}{f}$, the output returns 0.0.

Name	Description
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semiannual par yields set Frequency = 2. This output is calculated using the formula $$\mathrm{ParYield}(f, C, \tau, S) = f\frac{1 - Z(C, \tau, S)}{\sum_{n=1}^{f\times\tau} Z\left(C, \frac{n}{f}, S\right)}$$ where: • f is the frequency. • C is the credit class. • τ is the maturity. • S is the seniority. • $Z(C, \tau, S)$ is the zero coupon bond price (with credit class C, maturity τ and seniority S) based on this nominal yield curve and the primary credit model for this economy.
ParYieldSpread [Frequency, CreditClass, Maturity, Seniority]	The application calculates the par yield spread as the difference between the credit-risky par yield and the risk-free par yield for the default nominal yield curve.
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another.
ConditionalTransitionProbability [InterestRateModel, EquityAsset, StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another over the previous time step, conditional on the selected equity ZScore shock, which is decorrelated with the selected yield curve shocks.

Analysis tests

Name	Description
Initial Credit Spread Curve	Allows you to output the annually compounded multiplicative spot spreads as at time zero for a defined credit class, seniority, and set number of maturities.
Bond Market Instrument Test	Prices the bonds that you define, at time zero. Also calculates the annually compounded bond yields. **Note** If you enter multiple bonds, each appears as a separate line in the **Selected** list. However, the application saves all the bonds that you enter to the same analysis file, therefore the application takes the **Write header row** and **Folder** values from the first bond that you define.

RealWorldDynamics [G2Dynamics]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models changes in credit ratings from a baseline transition probability matrix. The transition matrix is evolved over time via the stochastic credit drivers.

Input variables

Name	Description
TransitionProbabilityMatrix	Defines the probabilities of a bond changing credit rating over one year. The matrix is used by the application to construct a baseline generator matrix.
LoadingFactors	Specifies the transformation of the baseline generator matrix to the stochastic generator matrix. C[0] is the constant term and C[1] to C[7] are the coefficients of the stochastic drivers.

RealWorldDynamics [G3Dynamics]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Use G3Dynamics for a default-only model of credit ratings.

Input variables

Name	Description
LoadingFactors	The application uses the loading factors for calculating the default intensity from the stochastic drivers.

RiskNeutralDynamics [G2Dynamics]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models changes in credit ratings from a baseline transition probability matrix. The transition matrix is evolved over time via the stochastic credit drivers.

Input variables

Name	Description
TransitionProbabilityMatrix	Defines the probabilities of a bond changing credit rating over one year. The matrix is used by the application to construct a baseline generator matrix.
LoadingFactors	Specifies the transformation of the baseline generator matrix to the stochastic generator matrix. C[0] is the constant term and C[1] to C[7] are the coefficients of the stochastic drivers.

RiskNeutralDynamics[G3Dynamics]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Use G3Dynamics for a default-only model of credit ratings.

Input variables

Name	Description
LoadingFactors	The application uses the loading factors for calculating the default intensity from the stochastic drivers.

Driver1 to Driver7 [SingleTermPremiumCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model.

Input variables

Name	Description	Conditions
Alpha	The mean reversion rate of the stochastic credit driver.	
Sigma	The volatility of the stochastic credit driver.	
Mu	The mean reversion level of the stochastic credit driver.	
StartVal	The initial value of the stochastic credit driver.	
SystematicComponent	The correlation between the credit driver shock and the systematic credit shock.	
MarketPriceOfRisk	The market price of risk.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [DualTermPremiumCIR]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model.

Input variables

Name	Description	Conditions
StartVal	The initial value of the stochastic credit driver.	
RealWorldMu	The real-world mean reversion level of the stochastic credit driver.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMu	The risk-neutral mean reversion level of the stochastic credit driver.	
RealWorldAlpha	The real-world rate of mean reversion of the stochastic credit driver.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralAlpha	The risk-neutral rate of mean reversion of the stochastic credit driver.	
Sigma	The volatility of the stochastic credit driver.	
SystematicComponent	The correlation between the credit driver shock and the systematic credit shock.	

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [SingleTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	Enter the following parameters for each time period: • **Years**—The length of the time period. • **Alpha**—The rate of mean reversion of the stochastic credit driver. • **Mu**—The mean of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver. • **MarketPriceOfRisk**—The market price of risk for the stochastic credit driver. Used for real world simulations only.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

Driver1 to Driver7 [DualTermPremiumCIRTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Drives the stochastic variations of the credit model. You can set up the model for multiple time periods of different lengths.

Input variables

Name	Description
Parameters	The time-varying parameters of the stochastic process. Fill the following fields for each time period: • **Years**—The number of years in the time period. • **RiskNeutralAlpha**—The risk-neutral rate of mean reversion of the stochastic credit driver. • **RiskNeutralMu**—The risk-neutral mean reversion level of the stochastic credit driver. • **Sigma**—The volatility of the stochastic credit driver. • **RealWorldAlpha**—The real-world rate of mean reversion of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**. • **RealWorldMu**—The real-world mean reversion level of the stochastic credit driver. Used only if you set the simulation-level parameter **UseRiskNeutralValuation** to **False**.
StartVal	The initial value of the stochastic credit driver.

Outputs

Name	Description
Value	The value of the stochastic credit driver.
AverageValue	The average value of the stochastic credit driver over the time step.

DummyCreditModel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A dummy credit model in which all bonds are default-free. Use the dummy credit model only if your license does not allow simulations of credit risk.

Outputs

Name	Description
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another. For the dummy credit model, the probability of transitioning to the same state is 1, and the probability of transitioning to another state is 0.
ConditionalTransitionProbability [InterestRateModel, EquityAsset, StartCreditClass, EndCreditClass]	The probability of transitioning from one credit class to another over the previous time step, conditional on the selected equity ZScore shock, which is decorrelated with the selected yield curve shocks. For the dummy credit model, the probability of transitioning to the same state is 1, and the probability of transitioning to another state is 0.

G2CreditStatisticalSpreadModel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

An RSG-only variation of the CreditModelG2, which models migrations between non-default credit states based on the underlying transition matrix, and models spread distributions based on risk drivers that you specify.

Input variables

Name	Description
Transition [CreditStatisticalTransition]	A model of credit transition probabilities.
Spread [CreditStatisticalSpread]	A credit spread model, using risk drivers to drive credit spreads.

Transition [CreditStatisticalTransition]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

A model of credit transition probabilities.

Input variables

Name	Description
TransitionProbabilityMatrix	Defines the probabilities of a bond changing credit rating over one year, excluding default. The model uses this input variable to derive rating transition probabilities over each simulation time step.

Outputs

Name	Description
TransitionProbability [StartCreditClass, EndCreditClass]	The probability of transitioning from the **StartCreditClass** to the **EndCreditClass**, over the last time step.

Spread [CreditStatisticalSpread]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

A credit spread model, using risk drivers to drive credit spreads.

Input variables

Name	Description
AAA	The risk driver for generating spreads for bonds with a AAA credit rating. Cannot be the NonCentralChiSquaredRiskDriver or the PoissonRiskDriverAutoCorrelated.
AA	The risk driver for generating spreads for bonds with a AA credit rating. Cannot be the NonCentralChiSquaredRiskDriver or the PoissonRiskDriverAutoCorrelated.
A	The risk driver for generating spreads for bonds with a A credit rating. Cannot be the NonCentralChiSquaredRiskDriver or the PoissonRiskDriverAutoCorrelated.
BBB	The risk driver for generating spreads for bonds with a BBB credit rating. Cannot be the NonCentralChiSquaredRiskDriver or the PoissonRiskDriverAutoCorrelated.
BB	The risk driver for generating spreads for bonds with a BB credit rating. Cannot be the NonCentralChiSquaredRiskDriver or the PoissonRiskDriverAutoCorrelated.
B	The risk driver for generating spreads for bonds with a B credit rating. Cannot be the NonCentralChiSquaredRiskDriver or the PoissonRiskDriverAutoCorrelated.

Name	Description
CCC	The risk driver for generating spreads for bonds with a CCC credit rating. Cannot be the NonCentralChiSquaredRiskDriver or the PoissonRiskDriverAutoCorrelated.
RiskDriverRepresentation	For risk drivers to represent spread changes, select **SpreadChanges**. For risk drivers to represent spread levels, select **SpreadLevels**.
InitialSpread	The initial credit spreads for each credit rating.

Outputs

Name	Description
CreditSpread [CreditClass]	The credit spread for the **CreditClass** that you specify. If you selected **AbsoluteLevel** for the **SpreadType**, this value is the value of the corresponding spread for the credit class. If you selected **AbsoluteChange** for the **SpreadType**, this is the sum of the value of **CreditSpread** at the previous time step and the value of the corresponding spread for the credit class.

MunicipalSpread

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Municipal spreads are adaptations to credit models taking into account tax benefits.

For more information about credit modeling in the Scenario Generator software, see the Credit Models methodology.

Input variables

Name	Description
CreditModel	The credit model that you want to use. The economy of the credit model that you select must match the economy of the municipal spread.
TaxRates	The implied tax rates, specified as a table of maturity versus credit class. If the required term for municipal bond calculations is less than the shortest term listed here, the tax rate for this shortest listed term is used. If the required term for municipal bond calculations is larger than the longest term listed here, the tax rate for the longest term listed is used.
InterpolateValues	Defines whether to use linear interpolation between terms specified in the **TaxRates** parameter. If you set this parameter to **False**, the software rounds down to the nearest term.

Outputs

Name	Description
TaxRate [CreditClass, Maturity]	The implied tax rate for the specified credit class and maturity that is actually being used. This output reflects any interpolation that is being done.

Name	Description
MunicipalSpread [CreditClass, Maturity, Seniority]	The municipal spot spread for the specified credit class, maturity, and seniority. $$\text{MunicipalSpread}(\text{CreditClass}, \text{Term}, \text{Seniority}, t) = \frac{(1 + \text{MunicipalSpread.NominalSpotRate}(\text{CreditClass}, \text{Term}, \text{Seniority}, t))}{(1 + \text{Economy.NominalSpotRate}(\text{Govt}, \text{Term}, t))} - 1$$
NominalSpotRate [CreditClass, Maturity,Seniority]	The annually compounded spot rate. This output is obtained from the nominal spot rate of the economy. $$\text{MunicipalSpread.NominalSpotRate}(\text{CreditClass}, \text{Term}, t) = \text{Economy.NominalSpotRate}(\text{CreditClass}, \text{Term}, t) \times (1 - \text{TaxRate}(\text{CreditClass}, \text{Term}, t))$$
ParYield [Frequency, CreditClass, Maturity, Seniority]	The par yield at the specified maturity, with the number of payments per annum specified by the **Frequency** parameter. *For example*, for semi-annual par yields set Frequency = 2. Calculated using the formula: $$\text{ParYield}(\text{Frequency}, \text{CreditClass}, \text{Maturity}, \text{Seniority}, t) = \frac{\text{Frequency} \times (1 - Z_N(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t))}{\sum_{s=1}^{\text{Frequency}\times\text{Maturity}} Z_N\left(\text{CreditClass}, \frac{s}{\text{Frequency}}, \text{Seniority}, t\right)}$$ where Z_N are zero coupon bond prices based on the municipal spread model and the primary nominal yield curve for this economy.

3.1.8 MacroEconomy [DummyMacroEconomy]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The dummy macro economy has no functionality. Use this model if you do not want to use macroeconomic modeling.

3.1.9 MacroEconomy [MacroG1]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A macro economy model, modeling demographics, labor market, national accounts, energy, and real estate. Except for Demographics, the high-level macro economy factor models are the same model type, and behave in the same manner. Likewise, the submodels all have the same model type and behavior. You can also define your own macro models and submodels, which behave in the same manner as the predefined macro models.

For more information about macroeconomic modeling, see the Macroeconomic Modeling methodology.

Submodels

Name	Description
Demographics	Contains population and household forecast data.
LabourMarket	Model for the labor market.
NationalAccounts	Model for national accounts.
Energy	Model for energy.
RealEstate	Model for real estate.

Addable submodels

Name	Description
GenericMacroModel	Enables you to define your own macro model.

Demographics

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Contains population and household forecast data.

Input variables

Name	Description
PopulationForecastData	The forecast data for the population. Time data must start from 0, and be strictly ascending. Contains the following values: • **Time**—The time point for the population data. • **Population**—The population data.
HouseholdsForecastData	The forecast data for the number of households. Time data must start from 0, and be strictly ascending. Contains the following values: • **Time**—The time point for the households data. • **Population**—The number of households data.

Outputs

Name	Description
Population	The population.
NumberOfHouseholds	The number of households.

LabourMarket

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for the labor market.

Submodels

Name	Description
UnemploymentRate	Model for the unemployment rate.
RealWageGrowth	Model for real wage growth.
NonFarmEmploymentGrowth	Model for nonfarm employment growth.
EquityWealth	Model for equity wealth.

Addable submodels

Name	Description
VectorTimeSeriesComponent	Enables you to define a macro model.

Input variables

Name	Description
ExogenousVariables	Variable definitions for variables used in calculations by the labor market submodels. Contains the following values: • **Name**—The name of the variable, for use in calculations. • **Output**—The simulation output to use for the variable value.
ExogenousInitialisationData	Initialization values for the variables. Defines time zero and previous values for the variables in **ExogenousVariables**.

UnemploymentRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for the unemployment rate.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, UnemploymentRate_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

RealWageGrowth

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for the real wage growth.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.

Name	Description
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, UnemploymentRate_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

NonFarmEmploymentGrowth

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for the nonfarm employment growth.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, UnemploymentRate_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.

Name	Description
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

EquityWealth

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for equity wealth.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, UnemploymentRate_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

VectorTimeSeriesComponent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to define a macro model.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, if you name your submodel VectorTimeSeriesComponent1, shocks are accessed with VectorTimeSeriesComponent1_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

NationalAccounts

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for national accounts.

Submodels

Name	Description
GDPGrowthRate	Model for the GDP growth rate.
Consumption	Model for consumption.

Addable submodels

Name	Description
VectorTimeSeriesComponent	Enables you to define a macro model.

Input variables

Name	Description
ExogenousVariables	Variable definitions for variables used in calculations by the labor market submodels. Contains the following values: • **Name**—The name of the variable, for use in calculations. • **Output**—The simulation output to use for the variable value.
ExogenousInitialisationData	Initialization values for the variables. Defines time zero and previous values for the variables in **ExogenousVariables**.

GDPGrowthRate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for the GDP growth rate.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*,

Name	Description
	a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, GDPGrowthRate_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

Consumption

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for consumption.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, GDPGrowthRate_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

VectorTimeSeriesComponent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to define a macro model.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, if you name your submodel VectorTimeSeriesComponent1, shocks are accessed with VectorTimeSeriesComponent1_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

Energy

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for energy.

Submodels

Name	Description
EnergyPriceGrowth	Model for energy price growth.

Addable submodels

Name	Description
VectorTimeSeriesComponent	Enables you to define a macro model.

Input variables

Name	Description
ExogenousVariables	Variable definitions for variables used in calculations by the labor market submodels. Contains the following values: • **Name**—The name of the variable, for use in calculations. • **Output**—The simulation output to use for the variable value.
ExogenousInitialisationData	Initialization values for the variables. Defines time zero and previous values for the variables in **ExogenousVariables**.

EnergyPriceGrowth

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for energy price growth.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.

Name	Description
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, EnergyPriceGrowth_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the Processors user guide section.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

VectorTimeSeriesComponent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to define a macro model.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, if you name your submodel VectorTimeSeriesComponent1, shocks are accessed with VectorTimeSeriesComponent1_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.

Name	Description
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

RealEstate

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for real estate.

Submodels

Name	Description
ResidentialPriceGrowth	Model for residential price growth.
CommercialPriceGrowth	Model for commercial price growth.

Addable submodels

Name	Description
VectorTimeSeriesComponent	Enables you to define a macro model.

Input variables

Name	Description
ExogenousVariables	Variable definitions for variables used in calculations by the labor market submodels. Contains the following values: • **Name**—The name of the variable, for use in calculations. • **Output**—The simulation output to use for the variable value.
ExogenousInitialisationData	Initialization values for the variables. Defines time zero and previous values for the variables in **ExogenousVariables**.

ResidentialPriceGrowth

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for residential price growth.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, ResidentialPriceGrowth_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

CommercialPriceGrowth

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Model for commercial price growth.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, ResidentialPriceGrowth_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

VectorTimeSeriesComponent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to define a macro model.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.

Name	Description
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, if you name your submodel VectorTimeSeriesComponent1, shocks are accessed with VectorTimeSeriesComponent1_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

GenericMacroModel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to define your own macro model.

Input variables

Name	Description
ExogenousVariables	Variable definitions for variables used in calculations by the labor market submodels. Contains the following values: • **Name**—The name of the variable, for use in calculations. • **Output**—The simulation output to use for the variable value.
ExogenousInitialisationData	Initialization values for the variables. Defines time zero and previous values for the variables in **ExogenousVariables**.

Addable submodels

Name	Description
VectorTimeSeriesComponent	Enables you to define a macro model.

VectorTimeSeriesComponent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to define a macro model.

Input variables

Name	Description
ModelledComponentName	The variable name that represents the modeled variable of the component in calculations.
Calculation	The calculation for the modeled variable. The calculation can reference the ModelledComponentName variable for the current model, and its siblings, and the exogenous variables defined in the parent model. The calculation can also reference the shocks for the current model and shocks for its siblings. Each variable in the calculation must be associated with a time series, where t is the current time in years. *For example*, a[t] is the current value of variable *a*, a[t-0.25] is the value of variable *a* at a simulation time three months ago. Shocks are accessed with the model name with the _dZ suffix, *for example*, if you name your submodel VectorTimeSeriesComponent1, shocks are accessed with VectorTimeSeriesComponent1_dZ[t]. The functions and operators available for MacroEconomy calculations match those available in processors, except that you cannot use t(), dt(), tlagged(n), or dtlagged(n). For more information about processors, see the *Scenario Generator User Guide*.
OutputTransformation	The calculation to transform the modeled variable into the component output. The OutputTransformation calculation can only reference the ModelledComponentName of the current model, not any exogenous variables or sibling modeled component names. The functions and operators available for output transformations match those available in processors. For more information about processors, see the Processors user guide section.
InitialisationData	Initialization values for the modeled component variable. Defines time zero and previous values.

Outputs

Name	Description
Value	The transformed output value representing the macroeconomic variable.
ModelledValue	The value before applying the output transformation.

3.1.10 RiskDrivers

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The risk drivers that can be included to model any other stochastic risks not explicitly captured by existing models. At this location in the tree structure, you can define the risk drivers to represent economy-specific quantities, *for example*, GDP or NAE. The choice of risk drivers at this location is the same as the choice available to the more general collections (that is, not within an economy) of risk drivers. For more information about the available risk drivers, see RiskDrivers.

4 Assets

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The assets container holds assets of several classes.

Submodels

Name	Description	Availability
EquityAssets	This container holds all the equity assets.	
FixedIncome	This container holds all the fixed income assets.	
Derivatives	This container holds all the assets whose value is derived from other quantities/entities.	
Parser	Container for the AssetParser model.	ESG
Funds	This container holds all the unit funds.	ESG

4.1 EquityAssets

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Each equity asset model has a volatility submodel.

You can choose to model Parent and Child Equity assets in a factor setup by adding the equity asset types ParentEquityAsset and ChildEquityAsset. As an alternative, you can model equity assets directly in the correlation matrix by choosing the equity asset types ParentEquityAssetCorrelationModel and ChildEquityAssetCorrelationModel. The fundamental difference between the two types is that the former splits risk into systematic risk driven by factor loadings and specific risk driven by the equity asset volatility model. The correlated version of the equity assets does not make this distinction and all risk is driven by the equity asset volatility model. For more information about the differences between the ways to model your equity assets, see the Correlation of Equity Assets methodology.

Containers

Name	Description
EquityAssetFactors	The factors that control a portion of the volatility and correlation structure of ParentEquityAsset and ChildEquityAsset submodels.

Addable submodels

Name	Description
ActuarialEquityModel	An actuarial equity model, styled on the American Academy of Actuaries Generator model.
ParentEquityAsset	Parent equities produce excess returns by direct exposure to several factors. They can be used to represent markets or market sectors.
ChildEquityAsset	Child equities returns are specified according to exposure to its parent (CAPM approach). They can be used to represent individual stocks.
ParentEquityAssetCorrelationModel	Essentially the same as a ParentEquityAsset except that its correlation is dealt with via the correlation matrix rather than the equity asset factors.
ChildEquityAssetCorrelationModel	Essentially the same as a ChildEquityAsset except that its correlation is dealt with via the correlation matrix rather than the equity asset factors.

Input variables

Name	Description
IncludeCashInTotalReturn	A flag which specifies how equity total returns are calculated for real world simulations. When IncludeCashInTotalReturn is set to its preset value, **True**, the total return comprises the risk free return on cash plus an excess return. When IncludeCashInTotalReturn is set to **False**, the total return is modeled directly, and does not include the risk free return on cash.

4.1.1 EquityAssetFactors

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Container for equity asset factors.

Submodels

Name	Description
Factor1	The equity asset factors, Factor1 to 6, are used to model the systematic component of an equity assets risk. The factors (specifically factor loadings) allow many equity assets to share common sources of risk, thus impose a correlation structure between the equity assets. Using factors allows many equity assets to be modeled in a parsimonious way. The alternative to the factor approach would be to model all equity assets directly in the correlation matrix using correlated versions of parent and child equity assets. However, this approach could result in a very large correlation matrix.
Factor2	
Factor3	
Factor4	
Factor5	
Factor6	

Factor1 to 6

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The equity asset factors are each modeled by a random walk. They are used to model systematic components of equity asset risk. The factors (specifically factor loadings) allow several equity assets to share common sources of risk, thus impose a correlation structure between the equity assets.

Submodels

Name	Description
Volatility	Possible models: • Volatility [FixedVolatility] • Volatility [DeterministicVolatility] • Volatility [NPDeterministicVolatility] • Volatility [SVJD] • Volatility [SVJD TD]

Input variables

Name	Description
Mu	The arithmetic mean return of the factor.
Gamma	Market price of risk (variance).
NumberOfSubdivisions	The number of time periods of each simulation time step that are used when the SVJD volatility model is active. This is because the SVJD model uses a Brownian bridge algorithm.

Outputs

Name	Description
Change	The change in the factor since the last output. Does not include contribution from jump component when underlying volatility model is SVJD or SVJDTD.

Volatility [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A constant volatility model.

Input variables

Name	Description
Value	The value of the constant volatility that applies for the whole of the simulation.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is constant if the fixed volatility model is selected. This is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.
SpotVolatility[JumpContribution]	The specific spot volatility of the equity asset with option to include or exclude the contribution of jumps.

Volatility [DeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Time-varying deterministic volatility. For more information, see the Time-Varying Deterministic Volatility methodology.

Input variables

Name	Description
SigmaNought	The instantaneous volatility at time 0.
SigmaInf	The long-term instantaneous volatility.
Alpha	The rate of change of the instantaneous volatility.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.
SpotVolatility[JumpContribution]	The spot volatility with option to include or exclude the contribution of jumps.

Volatility [NPDeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Non-parametric deterministic volatility. For more information about non-parametric deterministic volatility, see the Non-Parametric Deterministic Volatility methodology.

Input variables

Name	Description
Volatility.Years	The time maturity (in years) over which the excess volatility applies.
Volatility.ExcessVolatility	The excess volatility observed over a specified maturity.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash. For more information about volatility modeling, see the Volatility Modeling methodology.
SpotVolatility[JumpContribution]	The spot volatility with option to include or exclude the contribution of jumps.

Volatility [SVJD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion (SVJD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu + \sigma Z_i) - \text{JumpCompensator}\right\} - 1$$ where: • μ is the JumpMean parameter. • σ is the JumpVolatility parameter. • Z_i is a standard normal shock. • n is the NumberOfJumps over the time step. The JumpCompensator is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\text{JumpCompensator} = \exp\left(\mu + \frac{1}{2}\sigma^2\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where N is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.
SpotVolatility[JumpContribution]	The specific spot volatility of the equity asset with option to include or exclude the contribution of jumps.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
JumpMean	The expected size of the log jump.
ArrivalRate	The number of jumps expected per annum.
JumpVolatility	The volatility of the log jump.
RiskNeutralArrivalRate	The number of jumps expected per annum, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpMean	The expected size of the log jump, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpVolatility	The volatility of the log jump size, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NumberOfSubdivisions input to the parent model (that is, ParentEquityAsset, ParentEquityAssetCorrelationModel, or Factor). Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description	Conditions
MeanReversionRate	The rate of mean reversion of the stochastic variance process.	
Volatility	The volatility of the stochastic variance process.	

Name	Description	Conditions
MeanReversionLevel	The mean reversion level of the stochastic variance process.	
InitialValue	The initial value of the stochastic variance process.	
Correlation	The correlation between the stochastic variance shock and the log return shock.	
RiskNeutralMeanReversionRate	The mean reversion rate of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMeanReversionLevel	The mean reversion level of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The instantaneous value of the variance.
StandardisedVolatility	$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$ where *N* is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Volatility [SVJD TD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model, where the parameters of both models are time-dependent.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu_J(t) + \sigma_J(t)Z_i) - \bar{\mu}(t)\right\} - 1$$ where: • $\mu_J(t)$ is the JumpMean parameter. • $\sigma_J(t)$ is the JumpVolatility parameter. • Z_i is a standard normal shock. • n is the NumberOfJumps over the time step. The JumpCompensator $\mu_J(t)$ is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\bar{\mu}(t) = \exp\left(\mu_J(t) + \frac{1}{2}\sigma_J^2(t)\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N}V_{i-1}}$$ where: • N is the number of subdivisions. • γ is a scaling parameter. • V_i is the instantaneous variance of the SVJD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i}{\sqrt{\sum_{i=1}^{N}V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.
SpotVolatility[JumpContribution]	The specific spot volatility of the equity asset with option to include or exclude the contribution of jumps.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD TD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.
Parameters.ArrivalRate	The number of jumps expected per annum.
Parameters.JumpMean	The expected size of the log jump.
Parameters.JumpVolatility	The volatility of the log jump.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NrSubDivisions parameter. Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.
Parameters.VolatilityLevel	A time-dependent parameter which scales the stochastic variance process.
Parameters.MeanReversionRate	The rate of mean reversion of the stochastic variance process.
Parameters.MeanReversionLevel	The mean reversion level of the stochastic variance process.

Name	Description
Parameters.Volatility	The volatility of the stochastic variance process.
Parameters.Correlation	The correlation between the stochastic variance shock and the log return shock.
InitialValue	The initial value of the stochastic variance process.

Outputs

Name	Description
Value	The instantaneous value of the variance.
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where: • N is the number of subdivisions. • γ is a scaling parameter. • V_i is the instantaneous variance of the SVJD TD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i}{\sqrt{\sum_{i=1}^{N}V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

4.1.2 ActuarialEquityModel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An actuarial equity model, styled on the American Academy of Actuaries Generator model. Available when the simulation level EquityAssetCorrelationMethod parameter is set to CorrelationMatrix.

Input variables

Name	Description
Economy	The economy for this asset.
IntraSectorCorrelation	The correlation between assets within this market or sector.
InitialIndexValue	The initial index value for the TotalReturnIndex output.
ZScoreMPR	The market price of risk for the credit transition shock.
A	Stock return at zero volatility.

Name	Description
B	Linear coefficient of volatility in the function for mean return.
C	Quadratic coefficient of volatility in the function for mean return.
Sigma(0)	Starting volatility.
Phi	Strength of mean reversion.
Tau	Long run target volatility.
Sigma(v)	Monthly standard deviation of the log volatility process.
Sigma-	Minimum volatility (annualized).
Sigma+	Maximum volatility (annualized, before random component).
Sigma*	Maximum volatility (annualized, after random component).

Outputs

Name	Description
TotalReturn	The total return on this asset over the last time step.
AnnualisedTotalReturn	The annualized total return.
TotalReturnIndex	The total return index of this asset.
ExcessReturn	The excess return of this asset over the last time step.
ExcessReturnIndex	The excess return index of this asset.
RescaledTRI [StartVal]	The total return index of this asset, rescaled by a designated value.
Volatility	The total volatility of this asset.
StandardisedShock	The standardized shock of this asset.
ZScore	A normal approximation to the StandardisedShock.
DecorrelatedZScore [InterestRateModel]	A normal approximation to the StandardisedShock with correlation to the selected interest rate model removed.

Analysis tests

Name	Description
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

4.1.3 ParentEquityAsset

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Parent equity assets are addable models. Correlation of these assets is done via the equity asset factor loadings. For more information about the differences between ParentEquityAsset and ParentEquityAssetCorrelationModel, see the Correlation of Equity Assets methodology.

Be aware of the naming convention for equity assets that enables them to be calibrated using standard calibration files.

Submodels

Name	Description
DividendYield	Models the dividend yield dynamics.
DividendPayoutRatio	Models the dividend payout ratio dynamics.
MeanReturn	Models the long term mean return dynamics. To change the mean return model, right-click on MeanReturn, and select one of the following values: • MeanReturn [FixedEquityReturn] • MeanReturn [MeanRevertingEquityReturn] • MeanReturn [TimeDependentEquityReturn] • MeanReturn [EarningsBasedEquityReturn]
Sigma	The volatility structure of the asset. Possible models: • Sigma [FixedVolatility] • Sigma [DeterministicVolatility] • Sigma [NPDeterministicVolatility] • Sigma [SVJD] • Sigma [SVJDTD]

Addable submodels

Name	Description
RWOptionImpliedVolatility	This model has factors to explain volatility: level, skew, kurtosis, and term structure.

Input variables

Name	Description
Economy	The economy for this asset.
IntraSectorCorrelation	The correlation between assets within this sector or market.
FactorLoading	The strength of exposure of this asset to each of the factors.
Gamma	Market price of (variance) risk. Used for real world simulations only.
NumberOfSubdivisions	The number of subdivisions of each simulation time step. The number of subdivisions is used in any parent equity asset that uses the SVJD volatility model which uses the Brownian bridge algorithm.

Name	Description
Mu	The drift rate of the specific return of the equity asset.
ZScoreMPR	The market price of risk for the ZScore shock. Used for real world simulations only.
InitialIndexValue	The base value for index outputs.
IndividualRandomNumberScrambler	To adjust the random number stream for this model, enter a number > 0. The **IndividualRandomNumberScrambler** is appended to the model name, which the software uses to generate the random numbers. If this model is correlated with other models, then the random numbers in those models might change. For more information, see *Random Number Generation in the Scenario Generator: Seed-By-Trial Methodology*, available on the Customer Portal.

Outputs

Name	Description	Conditions
TotalReturn	The total return earned on the asset over the time step. The output at time zero is meaningless and a default value of 0 is given. $$\mathrm{TotalReturn}(t) = \mathrm{ExcessReturn}(t) + \mathrm{CashTotalReturn}(t)$$ Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.	
AnnualisedTotalReturn	The annualized total return. $$\mathrm{AnnualisedTotalReturn}(t) = \mathrm{AnnualisedIncomeReturn}(t) + \mathrm{AnnualisedCapitalChange}(t)$$	
TotalReturnIndex	The total return index of the asset. $$\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t - \Delta t) \times (1 + \mathrm{TotalReturn}(t))$$ where TotalReturnIndex(0) = InitialIndexValue.	
ExcessReturn	The return earned on the asset in excess of the risk free return. Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.	
ExcessReturnIndex	The excess return index of the asset. This output is calculated using the following equation: $$\mathrm{ExcessReturnIndex}(t) = \mathrm{ExcessReturnIndex}(t - \Delta t) \times (1 + \mathrm{ExcessReturn}(t))$$ where ExcessReturnIndex(0) = 1.	
RescaledTRI [StartVal]	The total return index (TRI) of this asset, rescaled by a designated value. This feature has been superseded by the InitialIndexValue parameter.	
CapitalChange	Price changes within the equity model are described by the output CapitalChange.Calculated using the equation: $$\mathrm{CapitalChange}(t) = \frac{\mathrm{Price}(t)}{\mathrm{Price}(t - \Delta t)} - 1 = \frac{1 + \mathrm{TotalReturn}(t)}{1 + \mathrm{DividendYield}(t) \times \Delta t} - 1$$ The output at time zero is meaningless and a default value of 0 is given.	

Name	Description	Conditions
AnnualisedCapitalChange	The annualized capital change. $$\text{AnnualisedCapitalChange}(t) = (1 + \text{CapitalChange}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.	
CapitalIndex	The capital index of the asset. $$\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$$ where CapitalIndex(0) = InitialIndexValue.	
IncomeReturn	The total return minus the capital change.	
AnnualisedIncomeReturn	The annualized income return. $$\text{AnnualisedIncomeReturn}(t) = (1 + \text{IncomeReturn}(t))^{\frac{1}{\Delta t}} - 1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.	
IncomeIndex	The income index is calculated from the capital index and the dividend yield. $$\text{IncomeIndex}(t) = \text{CapitalIndex}(t) \times \text{DividendYield}(t)$$	
EarningsYield	The earnings yield of an asset. $$\text{EarningsYield}(t) = \frac{\text{DividendYield}(t)}{\text{DividendPayout}(t)}$$	
EarningsIndex	The earnings index of an asset. $$\text{EarningsIndex}(t) = \frac{\text{IncomeIndex}(t)}{\text{DividendPayout}(t)} = \text{CapitalIndex}(t) \times \text{EarningsYield}(t)$$	
Volatility	The total volatility of the equity asset.	
SpotVolatility [JumpContribution]	The spot volatility of the equity asset with option to include or exclude the contribution of jumps.	
StandardisedShock	The standardized – that is, zero mean and unit dispersion – return of the asset. Its calculation depends on the selected CreditMigrationFactorMethod set at the simulation level. The standardized shock methods corresponding to CreditMigrationFactorMethod are: • EquityZScore: The default setting and the only supported standardized shock method up to SG 9.7.0. It is a normal approximation to the equity excess log return calculated by simplifying stochastic volatility and ignoring jumps. For information about its calculation, see the *Scenario Generator Methodology Guide*. • StandardisedExcessLogReturn and UnitVarianceSharpeRatio: For time step t, the standardized shock is calculated as $(R(t) - \mathbb{E}[R(t)])\sqrt{\mathbb{V}[R(t)]}$ where $R(t)$ is the equity excess log return, $\mathbb{E}[R(t)]$ is its unconditional mean, and $\mathbb{V}[R(t)]$ is its unconditional variance. In particular, stochastic volatility and jumps are	The **UnitVarianceSharpeRatio** option can only be used if **UseRiskNeutralValuation** is set to **False**.

Name	Description	Conditions
	included in this standardized shock hence its distribution is not approximately normal in general. The StandardisedExcessLogReturn and UnitVarianceSharpeRatio methods are supported for the FixedVolatility, DeterministicVolatility, NPDeterministicVolatility, and SVJD volatility models, and for the FixedEquityReturn, TimeDependentEquityReturn MeanReturn models, and the standardized shock calculation assumes the Gamma parameters of equity factors and parent equity assets are zero.	
ZScore	A standard normal approximation to the StandardisedShock.	Disabled if **CreditMigrationFactorMethod** is NOT set to **EquityZScore**.
DecorrelatedZScore [InterestRateModel]	A normal approximation to the StandardisedShock with mean equal to the ZScoreMPR input if UseRiskNeutralValuation is False else zero, and correlation to the selected interest rate model removed.	Disabled if **CreditMigrationFactorMethod** is NOT set to **EquityZScore**.
CreditMigrationFactor [InterestRateModel]	The common market component of the credit transition shock. Its calculation depends on the selected CreditMigrationFactorMethod set at the simulation level: • For **EquityZScore**: This output is identical to DecorrelatedZScore. • For **StandardisedExcessLogReturn**: For time step t, it is $\text{ZScoreMPR} + (R_{dc}(t) - \mathbb{E}[R_{dc}(t)])\sqrt{\mathbb{V}[R_{dc}(t)]}$ where $R_{dc}(t)$ is the equity excess log return decorrelated from InterestRateModel, $\mathbb{E}[R_{dc}(t)]$ is its unconditional mean, and $\mathbb{V}[R_{dc}(t)]$ is its unconditional variance. As stochastic volatility and jumps are included in this credit migration factor, its distribution is not approximately normal in general. • For **UnitVarianceSharpeRatio**: For time step t, it is $S(t) + \mu(t)/\sqrt{\mathbb{V}(t)}$ where $S(t)$ is the StandardisedShock, $\mu(t)$ is the unconditional expected equity excess log return without Itô terms, and $\mathbb{V}(t)$ is the unconditional variance of the equity excess log return. That is, the Sharpe ratio of this credit migration factor equals the Sharpe ratio of the equity asset. As mean returns, stochastic volatility, and jumps of parent equity assets are included in this credit migration factor, its distribution is not approximately normal in general. It does not depend on the InterestRateModel and ZScoreMPR inputs, and its correlation structure is not changed by any decorrelation procedure.	
EquityOptionImpliedVolatility [TimeToMaturity, StrikeType, StrikeRate]	This output is used for modeling equity option implied volatility and is only appropriate when using the SVJD equity volatility model in real world simulations. The output can be used when the ParentEquityAsset and the equity asset factors contain a total of exactly one or two SVJD volatility models. The calculations proceed as follows. First the option is priced (semi-)analytically based on the conditions prevailing at that time step, and then calculation of the implied volatility is attempted. There are a few cases when this fails: • When the analytical price is outside of the theoretical limits for an option price, the implied vol output is set to zero. This situation might come about because of tiny numerical inaccuracies in the numerical integration, most commonly when the option price is extremely small as might be the case when the option is far out-of-the-money, or close to the intrinsic price as might be the case when the option is deep in-the-money. • When the option is sufficiently far out-of-the-money or sufficiently deep in-the-money such that the option price sensitivity to volatility (that is, the Greek known as Vega) is zero, the implied volatility output is set to zero. In these cases, there are a wide range of volatilities that reproduce the	

Name	Description	Conditions
	option price to the limits of machine precision, and hence any solution obtained from the calculations would not be unique. The calculations for this output use the SVJD parameters (from the Variance and Jump submodels) called "RiskNeutralMeanReversionRate", "RiskNeutralMeanReversionLevel", "RiskNeutralArrivalRate", "RiskNeutralJumpMean", and "RiskNeutralJumpVolatility" (instead of "MeanReversionRate", "MeanReversionLevel", "ArrivalRate", "JumpMean", and "JumpVolatility", respectively). The parameter TimeToMaturity is the number of years before maturity of the option, StrikeType defines the way the actual StrikeRate is specified and used. The choices for the StrikeType parameter are as follows: • SpotStrike1—The Strike is expressed as a proportion of the spot price of the underlying asset at time zero. $$\text{StrikePrice} = \text{StrikeRate} \times \text{TotalReturnIndex}(0) = \text{StrikeRate}$$ In essence, this is an absolute strike that is fixed for all time steps. Using this form of StrikeType makes it highly probable that long term (call) options finish out-of-the-money. • SpotStrike2—The Strike is expressed as a proportion of the spot price of the underlying asset at the current time t. $$\text{StrikePrice} = \text{StrikeRate} \times \text{TotalReturnIndex}(t)$$ • ForwardStrike1—The Strike is expressed as a proportion of the forward price of the underlying asset at time zero. $$\text{StrikePrice} = \text{StrikeRate} \times \frac{\text{TotalReturnIndex}(0)}{Z(\text{TimeToMaturity}, 0)}$$ Using this form of StrikeType makes it highly probable that long term (call) options finish out-of-the-money. • ForwardStrike2—The Strike is expressed as a proportion of the forward price of the underlying asset at the current time t. $$\text{StrikePrice} = \text{StrikeRate} \times \frac{\text{TotalReturnIndex}(t)}{Z(\text{TimeToMaturity}, t)}$$ where $Z(\text{TimeToMaturity}, t)$ is the riskless zero coupon bond price with maturity of TimeToMaturity evaluated at the current time t.	
Payment	The dividend payment.	
RealCapitalIndex	The capital index of this asset adjusted for realized inflation.	Only available when the MeanReturn model is **EarningsBasedEquityReturn**
CyclicallyAdjustedEarningsYield	The cyclically adjusted real earnings per share divided by the real capital index.	Only available when the MeanReturn model is **EarningsBasedEquityReturn**

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the base economy of the simulation for all trials and takes the average.

Name	Description
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	Outputs time zero equity option prices and implied volatilities with option maturities corresponding to each time step. After selecting the test, enter the following values: • **OptionType**—**Call** or **Put**. • **StrikePrice**—The software calculates the strike of each contract as the time zero forward price for delivery of the total return index of the equity asset at the option maturity, multiplied by the **StrikePrice**. This method for calculating the strike is equivalent to selecting ForwardStrike2 in the corresponding EquityOptionImpliedVolatility output. • **IncludeAnalyticVol**—**True** or **False**. For equity assets where you have set the Sigma submodel to **DeterministicVolatility**, **FixedVolatility**, **NPDeterministicVolatility**, or **SVJD**, you can choose to calculate analytic implied volatilities at time zero.
Local Currency Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	A local currency version of the Equity Option Implied Volatility Test described above. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

DividendYield

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend yield dynamics. Strong price returns tend to be followed by above average dividend growth, whereas equity falls tend to be followed by growth below average.

Input variables

Name	Description
Alpha	The rate of mean reversion.
Mu	The mean of the log of the dividend yield.
StartVal	The initial value of the dividend yield.
AssetReturnCorrelation	The correlation between changes in the dividend yield and the total return.
ZeroBoundFlag	Indicates whether a zero bound level is applied to the dividend yield.
ZeroBoundLevel	The level below which the dividend yield is forced to zero.

Outputs

Name	Description
Value	The dividend yield calculated over the time step. $$\begin{aligned}\text{DividendYield} &= \frac{1}{\Delta t}\frac{1+\text{TotalReturn}}{1+\text{CapitalChange}} - 1 \\ &= \frac{1}{\Delta t}\frac{\text{TotalReturn}-\text{CapitalChange}}{1+\text{CapitalChange}}\end{aligned}$$

DividendPayoutRatio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend payout ratio dynamics.

Input variables

Name	Description
Alpha	The rate of mean reversion of the dividend payout ratio.
Sigma	The volatility of the dividend payout ratio.
Mu	The mean of the log of the dividend payout ratio.
StartVal	The initial value.
AssetReturnCorrelation	The correlation between changes in the dividend payout ratio and the total return.

Outputs

Name	Description
Value	The ratio of dividends to earnings.

MeanReturn [FixedEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the long term mean return dynamics using a fixed equity return model.

Input variables

Name	Description
Value	The arithmetic risk premium from the asset-specific component.

MeanReturn [MeanRevertingEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the long term mean return dynamics using a mean reverting return model.

Input variables

Name	Description
Alpha	The drift of the stochastic process.
Sigma	The volatility of the stochastic process.
ExcessReturn	The mean of the stochastic process.
StartVal	The initial value of the stochastic process.

MeanReturn [TimeDependentEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the long-term mean return dynamics using a deterministic time-dependent equity return model.

Note If you run the simulation in risk-neutral mode, the software uses a mean return of zero and ignores the input variables described in the following table.

Input variables

Name	Description
Value	The arithmetic risk premium from the asset-specific component.
Smoothing	Specify whether the risk premium is a smooth function of time. If you want the risk premium to be a step function, select **False**. If you want the risk premium to be interpolated using a quadratic spline, select **True**.
InitialValue	The initial risk premium, used only when **Smoothing** is **True**.

MeanReturn [EarningsBasedEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the long-term mean return dynamics such that the return varies with the level of equity valuation.

Note This model is only valid when running a Real World projection. If you attempt a simulation run using this model with the UseRiskNeutralValuation parameter set to True, the software will produce a runtime error.

Submodels

Name	Description
CyclicallyAdjustedEarningsYield	The ratio of an average of historical real equity earnings per share to the current real share price.

Input variables

Name	Description
Value	The arithmetic risk premium from the asset-specific component.
Sensitivity	The sensitivity of the current period's equity return to the value of the Cyclically Adjusted Earnings Yield at the beginning of the current period.

CyclicallyAdjustedEarningsYield

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Input variables

Name	Description
Mu	The equilibrium value of the (annualized instantaneous) cyclically adjusted earnings yield.
StartVal	The initial value of the cyclically adjusted equity earnings yield.
Alpha	The decay factor used in calculating the exponentially weighted moving average of historical real equity earnings.
Inflation	The inflation model to use in the calculation of real equity earnings. Select from the inflation models available in the Economy of the equity asset.

Sigma [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A constant volatility model.

Input variables

Name	Description
Value	The value of the constant volatility that applies for the whole of the simulation.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is constant if the fixed volatility model is selected. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [DeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Time-varying deterministic volatility. For more information, see the Time-Varying Deterministic Volatility methodology.

Input variables

Name	Description
SigmaNought	The instantaneous volatility at time 0.
SigmaInf	The long-term instantaneous volatility.
Alpha	The rate of change of the instantaneous volatility.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [NPDeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Non-parametric deterministic volatility. For more information about non-parametric deterministic volatility, see the Non-Parametric Deterministic Volatility methodology.

Input variables

Name	Description
Volatility.Years	The time maturity (in years) over which the excess volatility applies.
Volatility.ExcessVolatility	The excess volatility observed over a specified maturity.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash. For more information about volatility modeling, see the Volatility Modeling methodology.

Sigma [SVJD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion (SVJD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu + \sigma Z_i) - \text{JumpCompensator}\right\} - 1$$ where: • μ is the JumpMean parameter. • σ is the JumpVolatility parameter. • Z_i is a standard normal shock. • n is the NumberOfJumps over the time step. The JumpCompensator is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\text{JumpCompensator} = \exp\left(\mu + \frac{1}{2}\sigma^2\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where *N* is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
JumpMean	The expected size of the log-jump.
ArrivalRate	The number of jumps expected per annum.
JumpVolatility	The volatility of the log-jump.

Name	Description
RiskNeutralArrivalRate	The number of jumps expected per annum, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpMean	The expected size of the log-jump, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpVolatility	The volatility of the log-jump size, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NumberOfSubdivisions input to the parent model (that is, ParentEquityAsset, ParentEquityAssetCorrelationModel, or Factor). Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description
MeanReversionRate	The rate of mean reversion of the stochastic variance process.
Volatility	The volatility of the stochastic variance process.
MeanReversionLevel	The mean reversion level of the stochastic variance process.
InitialValue	The initial value of the stochastic variance process.
Correlation	The correlation between the stochastic variance shock and the log return shock.
RiskNeutralMeanReversionRate	The mean reversion rate of the underlying stochastic variance process, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralMeanReversionLevel	The mean reversion level of the underlying stochastic variance process, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Outputs

Name	Description
Value	The instantaneous value of the variance.
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where N is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}\,Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Sigma [SVJDTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model, where the parameters of both models are time-dependent.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Name	Description
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu_J(t) + \sigma_J(t)Z_i) - \bar{\mu}(t)\right\} - 1$$ where: • $\mu_J(t)$ is the JumpMean parameter. • $\sigma_J(t)$ is the JumpVolatility parameter. • Z_i is a standard normal shock. • n is the NumberOfJumps over the time step. The JumpCompensator $\mu_J(t)$ is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\bar{\mu}(t) = \exp\left(\mu_J(t) + \frac{1}{2}\sigma_J^2(t)\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where: • *N* is the number of subdivisions. • γ is a scaling parameter. • V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i}{\sqrt{\sum_{i=1}^{N} V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD TD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.

Name	Description
Parameters.ArrivalRate	The number of jumps expected per annum.
Parameters.JumpMean	The expected size of the log jump.
Parameters.JumpVolatility	The volatility of the log jump.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NrSubDivisions parameter. Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.
Parameters.VolatilityLevel	A time-dependent parameter which scales the stochastic variance process.
Parameters.MeanReversionRate	The rate of mean reversion of the stochastic variance process.
Parameters.MeanReversionLevel	The mean reversion level of the stochastic variance process.
Parameters.Volatility	The volatility of the stochastic variance process.
Parameters.Correlation	The correlation between the stochastic variance shock and the log return shock.
InitialValue	The initial value of the stochastic variance process.

Outputs

Name	Description
Value	The instantaneous value of the variance.

Name	Description
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where: • N is the number of subdivisions. • γ is a scaling parameter. • V_i is the instantaneous variance of the SVJD TD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N} \sqrt{V_{i-1}} Z_i}{\sqrt{\sum_{i=1}^{N} V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

RWOptionImpliedVolatility

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model has factors to explain volatility: level, skew, kurtosis, and term structure.

Submodels

Name	Description
Skew	A one factor Vasicek process.
Kurtosis	A one factor Vasicek process.
TermStructure	A one factor Vasicek process.
Level	The volatility output of the parent equity asset, with scaling and/or displacement.

Input variables

Name	Description
FactorLoadings	Exposure to level, skew, kurtosis, and term structure.
SigmaInf	The long-term instantaneous volatility.

Outputs

Name	Description
ImpliedVolatility	The implied volatility of the factor, at the **Maturity** and **Strike** that you specify. Calculated using the formula: $$IV(t,K,T) = IV_\infty(K,T) + e^{-\alpha t}\left(IV_M(K,T) - IV_\infty(K,T) - \beta_{Lv}(K,T)Lv(0)\right) + \beta_{Lv}(K,T)Lv(t) + \beta_{Sk}(K,T)Sk(t) + \beta_{Kt}(K,T)Kt(t) + \beta_{Ts}(K,T)Ts(t)$$ where: • $IV(t,K,T)$ is the ImpliedVolatility output for time step t, Strike K, and Maturity T • $IV_\infty(K,T)$ is the IVInf column of FactorLoadings • α is Level.Alpha • $IV_M(K,T)$ is the InitialIV column of FactorLoadings • $\beta_f \ (f \in \{Lv, Sk, Kt, Ts\})$ are the LevelBeta, SkewBeta, KurtosisBeta, TermStructureBeta columns of FactorLoadings • $Lv(t), Sk(t), Kt(t), Ts(t)$ are the Value outputs of the Level, Skew, Kurtosis, TermStructure nodes

Skew

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The skew for the RWOptionImpliedVolatility model.

Input variables

Name	Description
Alpha	The rate of mean reversion of the stochastic process.
Sigma	The volatility of the stochastic process.
Mu	The mean reversion level of the stochastic process.
StartVal	The initial value of the stochastic process.

Outputs

Name	Description
Value	The skew value.

Kurtosis

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The kurtosis for the RWOptionImpliedVolatility model.

Input variables

Name	Description
Alpha	The rate of mean reversion of the stochastic process.
Sigma	The volatility of the stochastic process.
Mu	The mean reversion level of the stochastic process.
StartVal	The initial value of the stochastic process.

Outputs

Name	Description
Value	The kurtosis value.

TermStructure

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The term structure for the RWOptionImpliedVolatility model.

Input variables

Name	Description
Alpha	The rate of mean reversion of the stochastic process.
Sigma	The volatility of the stochastic process.
Mu	The mean reversion level of the stochastic process.
StartVal	The initial value of the stochastic process.

Outputs

Name	Description
Value	The term structure value.

Level

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The level for the RWOptionImpliedVolatility model.

Input variables

Name	Description
JumpVol	The constant jump volatility component in the SVJD model.
LevelScaling	The scaling between implied and realized volatility.
LevelDisplacement	The displacement, to shift the volatility distribution.
Alpha	The rate of mean reversion of the implied volatility surface.

Outputs

Name	Description
Value	The level value.

4.1.4 ChildEquityAsset

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Child equity assets are addable models. The returns of a Child equity asset are modeled according to exposure to its parent. *For example*, they can be used to represent individual stocks within an index (that is, the parent). The log-return is made up of the risk-free return, the exposure to its parent equity, a specific component, and an Itô term.

For more information about the differences between ChildEquityAsset and ChildEquityAssetCorrelationModel, see the Correlation of Equity Assets methodology.

Be aware of the naming convention for equity assets that enables them to be calibrated using standard calibration files.

Submodels

Name	Description
DividendYield	Models the dividend yield dynamics.
DividendPayoutRatio	Models the dividend payout ratio dynamics.

Name	Description
Alpha	The component of excess return not attributable to the parent asset. This submodel can be one of the following: • Alpha [FixedEquityReturn] • Alpha [TimeDependentEquityReturn]
Sigma	The volatility structure of the asset. Possible models: • Sigma [FixedVolatility] • Sigma [DeterministicVolatility] • Sigma [NPDeterministicVolatility] • Sigma [SVJD] • Sigma [SVJDTD]

Input variables

Name	Description
ParentAsset	The parent asset associated with this child asset.
Beta	The strength of exposure to the parent asset.
IntraSectorCorrelation	The correlation between assets within this sector or market.
NumberOfSubdivisions	The number of subintervals of each simulation time step. The number of subdivisions is used in models that use a Brownian bridge algorithm.
InitialIndexValue	The base value for index outputs.
IndividualRandomNumberScrambler	To adjust the random number stream for this model, enter a number > 0. The **IndividualRandomNumberScrambler** is appended to the model name, which the software uses to generate the random numbers. If this model is correlated with other models, then the random numbers in those models might change. For more information, see *Random Number Generation in the Scenario Generator: Seed-By-Trial Methodology*, available on the Customer Portal.

Outputs

Name	Description
TotalReturn	The total return earned on the asset over the time step. The output at time zero is meaningless and a default value of 0 is given. $\mathrm{TotalReturn}(t) = \mathrm{ExcessReturn}(t) + \mathrm{CashTotalReturn}(t)$ Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.
AnnualisedTotalReturn	The annualized total return. $\mathrm{AnnualisedTotalReturn}(t) = \mathrm{AnnualisedIncomeReturn}(t) + \mathrm{AnnualisedCapitalChange}(t)$
TotalReturnIndex	The total return index of the asset. $\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t - \Delta t) \times (1 + \mathrm{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue.
ExcessReturn	The return earned on the asset in excess of the risk free return. Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.

Name	Description
ExcessReturnIndex	The excess return index of the asset. This output is calculated using the following equation: $$\begin{aligned}&\mathrm{ExcessReturnIndex}(t)\\&\quad=\mathrm{ExcessReturnIndex}(t-\Delta t)\times(1+\mathrm{ExcessReturn}(t))\end{aligned}$$ where ExcessReturnIndex(0) = 1.
RescaledTRI [StartVal]	The total return index of this asset, rescaled to the specific starting value.
CapitalChange	Price changes within the equity model are described by the output CapitalChange. Calculated using the equation: $$\mathrm{CapitalChange}(t)=\frac{\mathrm{Price}(t)}{\mathrm{Price}(t-\Delta t)}-1=\frac{1+\mathrm{TotalReturn}(t)}{1+\mathrm{DividendYield}(t)\times\Delta t}-1$$ The output at time zero is meaningless and a default value of 0 is given.
AnnualisedCapitalChange	The annualized capital change. $$\mathrm{AnnualisedCapitalChange}(t)=(1+\mathrm{CapitalChange}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
CapitalIndex	The capital index of the asset $$\mathrm{CapitalIndex}(t)=\mathrm{CapitalIndex}(t-\Delta t)\times(1+\mathrm{CapitalChange}(t))$$ where CapitalIndex(0) = InitialIndexValue.
IncomeReturn	The total return minus the capital change.
AnnualisedIncomeReturn	The annualized income return. $$\mathrm{AnnualisedIncomeReturn}(t)=(1+\mathrm{IncomeReturn}(t))^{\frac{1}{\Delta t}}-1$$
IncomeIndex	The income index is calculated from the capital index and the dividend yield. $$\mathrm{IncomeIndex}(t)=\mathrm{CapitalIndex}(t)\times\mathrm{DividendYield}(t)$$
EarningsYield	The earnings yield of an asset: $$\mathrm{EarningsYield}(t)=\frac{\mathrm{DividendYield}(t)}{\mathrm{DividendPayout}(t)}$$
EarningsIndex	The earnings index of an asset. $$\begin{aligned}\mathrm{EarningsIndex}(t)&=\frac{\mathrm{IncomeIndex}(t)}{\mathrm{DividendPayout}(t)}\\&=\mathrm{CapitalIndex}(t)\times\mathrm{EarningsYield}(t)\end{aligned}$$
Volatility	The total volatility of the equity asset.
SpotVolatility[JumpContribution]	The spot volatility of the equity asset with option to include or exclude the contribution of jumps.
ZScore	The standardized return of an asset.
Payment	The dividend payment.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the base economy of the simulation for all trials and takes the average.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	Outputs time zero equity option prices and implied volatilities with option maturities corresponding to each time step. After selecting the test, enter the following values: • **OptionType**—**Call** or **Put**. • **StrikePrice**—The software calculates the strike of each contract as the time zero forward price for delivery of the total return index of the equity asset at the option maturity, multiplied by the **StrikePrice**. This method for calculating the strike is equivalent to selecting ForwardStrike2 in the corresponding EquityOptionImpliedVolatility output. • **IncludeAnalyticVol**—**True** or **False**. For equity assets where you have set the Sigma submodel to **DeterministicVolatility**, **FixedVolatility**, **NPDeterministicVolatility**, or **SVJD**, you can choose to calculate analytic implied volatilities at time zero.
Local Currency Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	A local currency version of the Equity Option Implied Volatility Test described above. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

DividendYield

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend yield dynamics. Strong price returns tend to be followed by above average dividend growth, whereas equity falls tend to be followed by growth below average.

Input variables

Name	Description
Alpha	The rate of mean reversion.
Mu	The mean of the log of the dividend yield.
StartVal	The initial value of the dividend yield.
AssetReturnCorrelation	The correlation between changes in the dividend yield and the total return.
ZeroBoundFlag	Indicates whether a zero bound level is applied to the dividend yield.
ZeroBoundLevel	The level below which the dividend yield is forced to zero.

Outputs

Name	Description
Value	The dividend yield calculated over the time step. $$\begin{aligned}\text{DividendYield} &= \frac{1}{\Delta t}\frac{1+\text{TotalReturn}}{1+\text{CapitalChange}} - 1\\ &= \frac{1}{\Delta t}\frac{\text{TotalReturn}-\text{CapitalChange}}{1+\text{CapitalChange}}\end{aligned}$$

DividendPayoutRatio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend payout ratio dynamics.

Input variables

Name	Description
Alpha	The rate of mean reversion of the dividend payout ratio.
Sigma	The volatility of the dividend payout ratio.
Mu	The mean of the log of the dividend payout ratio.
StartVal	The initial value.
AssetReturnCorrelation	The correlation between changes in the dividend payout ratio and the total return.

Outputs

Name	Description
Value	The ratio of dividends to earnings.

Alpha [FixedEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A fixed equity return model.

Input variables

Name	Description
Value	The arithmetic risk premium from the asset-specific component.

Outputs

Name	Description
Value	The continuously compounded arithmetic expected risk premium associated with the specific component of the excess return.

Alpha [TimeDependentEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A time-dependent equity return model. Available only in real-world mode, that is, the simulation-level UseRiskNeutralValuation parameter is False.

Input variables

Name	Description
Value	The arithmetic expected risk premium from the asset-specific component, specified as piecewise constant continuously compounded rates applying during the given time intervals.
Smoothing	Select whether smoothing should be applied to the time-dependent risk premium.
InitialValue	The initial arithmetic risk premium from the asset-specific component. Used only when **Smoothing** is **True**.

Outputs

Name	Description
Value	The continuously compounded arithmetic expected risk premium associated with the specific component of the excess return.

Sigma [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A constant volatility model.

Input variables

Name	Description
Value	The value of the constant volatility that applies for the whole of the simulation.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is constant if the fixed volatility model is selected. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [DeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Time-varying deterministic volatility. For more information, see the Time-Varying Deterministic Volatility methodology.

Input variables

Name	Description
SigmaNought	The instantaneous volatility at time 0.
SigmaInf	The long-term instantaneous volatility.
Alpha	The rate of change of the instantaneous volatility.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [NPDeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Non-parametric deterministic volatility. For more information about non-parametric deterministic volatility, see the Non-Parametric Deterministic Volatility methodology.

Input variables

Name	Description
Volatility.Years	The time maturity (in years) over which the excess volatility applies.
Volatility.ExcessVolatility	The excess volatility observed over a specified maturity.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash. For more information about volatility modeling, see the Volatility Modeling methodology.

Sigma [SVJD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion (SVJD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Name	Description
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu + \sigma Z_i) - \text{JumpCompensator}\right\} - 1$$ where: • μ is the JumpMean parameter • σ is the JumpVolatility parameter • Z_i is a standard normal shock • n is the NumberOfJumps over the time step. The JumpCompensator is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\text{JumpCompensator} = \exp\left(\mu + \frac{1}{2}\sigma^2\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where *N* is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
JumpMean	The expected size of the log-jump.
ArrivalRate	The number of jumps expected per annum.
JumpVolatility	The volatility of the log-jump.
RiskNeutralArrivalRate	The number of jumps expected per annum, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpMean	The expected size of the log-jump, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Name	Description
RiskNeutralJumpVolatility	The volatility of the log-jump size, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NumberOfSubdivisions input to the parent model (that is, ParentEquityAsset, ParentEquityAssetCorrelationModel, or Factor). Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description	Condition
MeanReversionRate	The rate of mean reversion of the stochastic variance process.	
Volatility	The volatility of the stochastic variance process.	
MeanReversionLevel	The mean reversion level of the stochastic variance process.	
InitialValue	The initial value of the stochastic variance process.	
Correlation	The correlation between the stochastic variance shock and the log return shock.	
RiskNeutralMeanReversionRate	The mean reversion rate of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMeanReversionLevel	The mean reversion level of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The instantaneous value of the variance.
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where N is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}\,Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Sigma [SVJDTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model, where the parameters of both models are time-dependent.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Name	Description
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu_J(t) + \sigma_J(t)Z_i) - \bar{\mu}(t)\right\} - 1$$ where: • $\mu_J(t)$ is the JumpMean parameter • $\sigma_J(t)$ is the JumpVolatility parameter • Z_i is a standard normal shock • n is the NumberOfJumps over the time step. The JumpCompensator $\mu_J(t)$ is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\bar{\mu}(t) = \exp\left(\mu_J(t) + \frac{1}{2}\sigma_J^2(t)\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N}V_{i-1}}$$ where: • N is the number of subdivisions • γ is a scaling parameter • V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i}{\sqrt{\sum_{i=1}^{N}V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD TD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.

Name	Description
Parameters.ArrivalRate	The number of jumps expected per annum.
Parameters.JumpMean	The expected size of the log jump.
Parameters.JumpVolatility	The volatility of the log jump.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NrSubDivisions parameter. Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.
Parameters.VolatilityLevel	A time-dependent parameter which scales the stochastic variance process.
Parameters.MeanReversionRate	The rate of mean reversion of the stochastic variance process.
Parameters.MeanReversionLevel	The mean reversion level of the stochastic variance process.
Parameters.Volatility	The volatility of the stochastic variance process.
Parameters.Correlation	The correlation between the stochastic variance shock and the log return shock.
InitialValue	The initial value of the stochastic variance process.

Outputs

Name	Description
Value	The instantaneous value of the variance.

Name	Description
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where: • N is the number of subdivisions • γ is a scaling parameter • V_i is the instantaneous variance of the SVJD TD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i}{\sqrt{\sum_{i=1}^{N} V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

4.1.5 ParentEquityAssetCorrelationModel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

ParentEquityAssetCorrelationModels are similar to ParentEquityAssets except that they are directly correlated to other assets via the correlation matrix rather than indirectly using the EquityAssetFactors. For more information about ParentEquityAssets, see ParentEquityAsset. For more information about the differences between ParentEquityAsset and ParentEquityAssetCorrelationModel, see the Correlation of Equity Assets methodology.

Be aware of the naming convention for equity assets that enables them to be calibrated using standard calibration files.

Submodels

Name	Description
DividendYield	Models the dividend yield dynamics.
DividendPayoutRatio	Models the dividend payout ratio dynamics.
MeanReturn	Models the long term mean return dynamics. Possible models: • MeanReturn [FixedEquityReturn] • MeanReturn [MeanRevertingEquityReturn] • MeanReturn [TimeDependentEquityReturn]
Sigma	The volatility structure of the asset. Possible models: • Sigma [FixedVolatility] • Sigma [DeterministicVolatility] • Sigma [NPDeterministicVolatility]

Name	Description
	• Sigma [SVJD] • Sigma [SVJDTD]

Input variables

Name	Description
Economy	The economy for this asset.
IntraSectorCorrelation	The correlation between assets within this sector or market.
Gamma	Market price of (variance) risk. Used for real world simulations only.
NumberOfSubdivisions	The number of subdivisions of each simulation time step. The number of subdivisions is used in any parent equity asset that uses the SVJD volatility model which uses the Brownian bridge algorithm.
Mu	The drift rate of the specific return of the equity asset.
InitialIndexValue	The base value for index outputs.
ZScoreMPR	The market price of risk for the ZScore shock. Used for real world simulations only.
IndividualRandomNumberScrambler	To adjust the random number stream for this model, enter a number > 0. The **IndividualRandomNumberScrambler** is appended to the model name, which the software uses to generate the random numbers. If this model is correlated with other models, then the random numbers in those models might change. For more information, see *Random Number Generation in the Scenario Generator: Seed-By-Trial Methodology*, available on the Customer Portal.

Outputs

Name	Description	Conditions
TotalReturn	The total return earned on the asset over the time step. The output at time zero is meaningless and a default value of 0 is given. $\text{TotalReturn}(t) = \text{ExcessReturn}(t) + \text{CashTotalReturn}(t)$ Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.	
AnnualisedTotalReturn	The annualized total return. $\text{AnnualisedTotalReturn}(t) = \text{AnnualisedIncomeReturn}(t) + \text{AnnualisedCapitalChange}(t)$	
TotalReturnIndex	The total return index of the asset. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue.	
ExcessReturn	The return earned on the asset in excess of the risk free return. Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.	

Name	Description	Conditions
ExcessReturnIndex	The excess return index of the asset. This output is calculated using the following equation: $\mathrm{ExcessReturnIndex}(t) = \mathrm{ExcessReturnIndex}(t-\Delta t) \times (1 + \mathrm{ExcessReturn}(t))$ where ExcessReturnIndex(0) = 1.	
RescaledTRI [StartVal]	The total return index (TRI) of this asset, rescaled by a designated value. This feature has been superseded by the InitialIndexValue parameter.	
CapitalChange	Price changes within the equity model are described by the output CapitalChange. Calculated using the equation: $\mathrm{CapitalChange}(t) = \frac{\mathrm{Price}(t)}{\mathrm{Price}(t-\Delta t)} - 1 = \frac{1 + \mathrm{TotalReturn}(t)}{1 + \mathrm{DividendYield}(t) \times \Delta t} - 1$ The output at time zero is meaningless and a default value of 0 is given.	
AnnualisedCapitalChange	The annualized capital change. $\mathrm{AnnualisedCapitalChange}(t) = (1 + \mathrm{CapitalChange}(t))^{\frac{1}{\Delta t}} - 1$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.	
CapitalIndex	The capital index of the asset $\mathrm{CapitalIndex}(t) = \mathrm{CapitalIndex}(t-\Delta t) \times (1 + \mathrm{CapitalChange}(t))$ where CapitalIndex(0) = InitialIndexValue.	
IncomeReturn	The total return minus the capital change.	
AnnualisedIncomeReturn	The annualized income return. $\mathrm{AnnualisedIncomeReturn}(t) = (1 + \mathrm{IncomeReturn}(t))^{\frac{1}{\Delta t}} - 1$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.	
IncomeIndex	The income index is calculated from the capital index and the dividend yield. $\mathrm{IncomeIndex}(t) = \mathrm{CapitalIndex}(t) \times \mathrm{DividendYield}(t)$	
EarningsYield	The earnings yield of an asset: $\mathrm{EarningsYield}(t) = \frac{\mathrm{DividendYield}(t)}{\mathrm{DividendPayout}(t)}$	
EarningsIndex	The earnings index of an asset. $\mathrm{EarningsIndex}(t) = \frac{\mathrm{IncomeIndex}(t)}{\mathrm{DividendPayout}(t)} = \mathrm{CapitalIndex}(t) \times \mathrm{EarningsYield}(t)$	

Name	Description	Conditions
Volatility	The total volatility of the equity asset.	
SpotVolatility[JumpContribution]	The spot volatility of the equity asset with option to include or exclude the contribution of jumps.	
StandardisedShock	The standardized – that is, zero mean and unit dispersion – return of the asset. Its calculation depends on the selected CreditMigrationFactorMethod set at the simulation level. The standardized shock methods corresponding to CreditMigrationFactorMethod are: • EquityZScore: The default setting and the only supported standardized shock method up to SG 9.7.0. It is a normal approximation to the equity excess log return calculated by simplifying stochastic volatility and ignoring jumps. For information about its calculation, see the *Scenario Generator Methodology Guide*. • StandardisedExcessLogReturn and UnitVarianceSharpeRatio: For time step t, the standardized shock is calculated as $(R(t) - \mathbb{E}[R(t)])\sqrt{\mathbb{V}[R(t)]}$ where $R(t)$ is the equity excess log return, $\mathbb{E}[R(t)]$ is its unconditional mean, and $\mathbb{V}[R(t)]$ is its unconditional variance. In particular, stochastic volatility and jumps are included in this standardized shock hence its distribution is not approximately normal in general. The StandardisedExcessLogReturn and UnitVarianceSharpeRatio methods are supported for the FixedVolatility, DeterministicVolatility, NPDeterministicVolatility, and SVJD volatility models, and for the FixedEquityReturn, TimeDependentEquityReturn MeanReturn models, and the standardized shock calculation assumes Gamma is zero.	The **UnitVarianceSharpeRatio** option can only be used if **UseRiskNeutralValuation** is set to **False**.
ZScore	A standard normal approximation to the StandardisedShock.	Disabled if **CreditMigrationFactorMethod** is NOT set to **EquityZScore**.
DecorrelatedZScore [InterestRateModel]	A normal approximation to the StandardisedShock with mean equal to the ZScoreMPR input if UseRiskNeutralValuation is False else zero, and correlation to the selected interest rate model removed.	Disabled if **CreditMigrationFactorMethod** is NOT set to **EquityZScore**.
CreditMigrationFactor [InterestRateModel]	The common market component of the credit transition shock. Its calculation depends on the selected CreditMigrationFactorMethod set at the simulation level: • EquityZScore: Identical to DecorrelatedZScore. • StandardisedExcessLogReturn: For time step t, it is $\text{ZScoreMPR} + (R_{dc}(t) - \mathbb{E}[R_{dc}(t)])\sqrt{\mathbb{V}[R_{dc}(t)]}$ where $R_{dc}(t)$ is the equity excess log return decorrelated from InterestRateModel, $\mathbb{E}[R_{dc}(t)]$ is its unconditional mean, and $\mathbb{V}[R_{dc}(t)]$ is its unconditional variance. As stochastic volatility and jumps are included in this credit migration factor, its distribution is not approximately normal in general. • UnitVarianceSharpeRatio: It can only be used if UseRiskNeutralValuation is set to False. For time step t, it is $S(t) + \mu(t)/\sqrt{\mathbb{V}(t)}$ where $S(t)$ is the StandardisedShock, $\mu(t)$ is the unconditional expected equity excess log return without Itô terms, and $\mathbb{V}(t)$ is the unconditional variance of the equity excess log return. That is, the Sharpe ratio of this credit migration factor equals the Sharpe ratio of the equity asset. As mean returns, stochastic volatility, and jumps of parent equity assets are included in this credit migration factor, its distribution is not approximately normal in general. It does not depend on the InterestRateModel and ZScoreMPR inputs, and its correlation structure is not changed by any decorrelation procedure.	

Name	Description	Conditions
EquityOptionImpliedVolatility [TimeToMaturity, StrikeType, StrikeRate]	This output is used for modeling equity option implied volatility and can be used when the ParentEquityAssetCorrelationModel uses the SVJD volatility model. The calculations proceed as follows. First the option is priced (semi-)analytically based on the conditions prevailing at that time step, and then calculation of the implied volatility is attempted. There are a few cases when this fails: • When the analytical price is outside of the theoretical limits for an option price, the implied vol output is set to zero. This might come about because of tiny numerical inaccuracies in the numerical integration, most commonly when the option price is extremely small as might be the case when the option is far out-of-the-money, or close to the intrinsic price as might be the case when the option is deep in-the-money. • When the option is sufficiently far out-of-the-money or sufficiently deep in-the-money such that the option price sensitivity to volatility (that is, the Greek known as Vega) is zero, the implied volatility output is set to zero. In these cases, there are a wide range of volatilities that reproduce the option price to the limits of machine precision, and hence any solution obtained from the calculations would not be unique. If UseRiskNeutralValuation is set to True, the calculations for this output use the "MeanReversionRate", "MeanReversionLevel", "ArrivalRate", "JumpMean", and "JumpVolatility" parameters. If UseRiskNeutralValuation is set to False, the calculations use the "RiskNeutralMeanReversionRate", "RiskNeutralMeanReversionLevel", "RiskNeutralArrivalRate", "RiskNeutralJumpMean", and "RiskNeutralJumpVolatility" parameters. The parameter TimeToMaturity is the number of years before maturity of the option, StrikeType defines the way the actual StrikeRate is specified and used. The choices for the StrikeType parameter are as follows: • SpotStrike1—The Strike is expressed as a proportion of the spot price of the underlying asset at time zero. $\mathrm{StrikePrice} = \mathrm{StrikeRate} \times \mathrm{TotalReturnIndex}(0) = \mathrm{StrikeRate}$ In essence, this is an absolute strike that is fixed for all time steps. Using this form of StrikeType makes it highly probable that long term (call) options finish out-of-the-money. • SpotStrike2—The Strike is expressed as a proportion of the spot price of the underlying asset at the current time *t*. $\mathrm{StrikePrice} = \mathrm{StrikeRate} \times \mathrm{TotalReturnIndex}(t)$ • ForwardStrike1—The Strike is expressed as a proportion of the forward price of the underlying asset at time zero. $\mathrm{StrikePrice} = \mathrm{StrikeRate} \times \dfrac{\mathrm{TotalReturnIndex}(0)}{Z(\mathrm{TimeToMaturity}, 0)}$ Using this form of StrikeType makes it highly probable that long term (call) options finish out-of-the-money. • ForwardStrike2—The Strike is expressed as a proportion of the forward price of the underlying asset at the current time t. $\mathrm{StrikePrice} = \mathrm{StrikeRate} \times \dfrac{\mathrm{TotalReturnIndex}(t)}{Z(\mathrm{TimeToMaturity}, t)}$ where $Z(\mathrm{TimeToMaturity}, t)$ is the riskless zero coupon bond price with maturity of TimeToMaturity evaluated at the current time *t*.	

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the base economy of the simulation for all trials and takes the average.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	Outputs time zero equity option prices and implied volatilities with option maturities corresponding to each time step. After selecting the test, enter the following values: • **OptionType**—**Call** or **Put**. • **StrikePrice**—The software calculates the strike of each contract as the time zero forward price for delivery of the total return index of the equity asset at the option maturity, multiplied by the **StrikePrice**. This method for calculating the strike is equivalent to selecting ForwardStrike2 in the corresponding EquityOptionImpliedVolatility output. • **IncludeAnalyticVol**—**True** or **False**. For equity assets where you have set the Sigma submodel to **DeterministicVolatility**, **FixedVolatility**, **NPDeterministicVolatility**, or **SVJD**, you can choose to calculate analytic implied volatilities at time zero.
Local Currency Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	A local currency version of the Equity Option Implied Volatility Test described above. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

DividendYield

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend yield dynamics. Strong price returns tend to be followed by above average dividend growth, whereas equity falls tend to be followed by growth below average.

Input variables

Name	Description
Alpha	The rate of mean reversion.
Mu	The mean of the log of the dividend yield.
StartVal	The initial value of the dividend yield.
AssetReturnCorrelation	The correlation between changes in the dividend yield and the total return.
ZeroBoundFlag	Indicates whether a zero bound level is applied to the dividend yield.

Name	Description
ZeroBoundLevel	The level below which the dividend yield is forced to zero.

Outputs

Name	Description
Value	The dividend yield calculated over the time step. $\begin{aligned}\text{DividendYield} &= \frac{1}{\Delta t}\frac{1+\text{TotalReturn}}{1+\text{CapitalChange}} - 1 \\ &= \frac{1}{\Delta t}\frac{\text{TotalReturn}-\text{CapitalChange}}{1+\text{CapitalChange}}\end{aligned}$

DividendPayoutRatio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend payout ratio dynamics.

Input variables

Name	Description
Alpha	The rate of mean reversion of the dividend payout ratio.
Sigma	The volatility of the dividend payout ratio.
Mu	The mean of the log of the dividend payout ratio.
StartVal	The initial value.
AssetReturnCorrelation	The correlation between changes in the dividend payout ratio and the total return.

Outputs

Name	Description
Value	The ratio of dividends to earnings.

MeanReturn [FixedEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the long term mean return dynamics using a fixed equity return model.

Input variables

Name	Description
Value	The arithmetic risk premium from the asset-specific component.

MeanReturn [MeanRevertingEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the long term mean return dynamics using a mean reverting return model.

Input variables

Name	Description
Alpha	The drift of the stochastic process.
Sigma	The volatility of the stochastic process.
ExcessReturn	The mean of the stochastic process.
StartVal	The initial value of the stochastic process.

MeanReturn [TimeDependentEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the long-term mean return dynamics using a deterministic time-dependent equity return model.

Note If you run the simulation in risk-neutral mode, the software uses a mean return of zero and ignores the input variables described in the following table.

Input variables

Name	Description
Value	The arithmetic risk premium from the asset-specific component.
Smoothing	Specify whether the risk premium is a smooth function of time. If you want the risk premium to be a step function, select **False**. If you want the risk premium to be interpolated using a quadratic spline, select **True**.

Name	Description
InitialValue	The initial risk premium, used only when **Smoothing** is **True**.

Sigma [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A constant volatility model.

Input variables

Name	Description
Value	The value of the constant volatility that applies for the whole of the simulation.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is constant if the fixed volatility model is selected. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [DeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Time-varying deterministic volatility. For more information, see the Time-Varying Deterministic Volatility methodology.

Input variables

Name	Description
SigmaNought	The instantaneous volatility at time 0.
SigmaInf	The long-term instantaneous volatility.
Alpha	The rate of change of the instantaneous volatility.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [NPDeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Non-parametric deterministic volatility. For more information about non-parametric deterministic volatility, see the Non-Parametric Deterministic Volatility methodology.

Input variables

Name	Description
Volatility.Years	The time maturity (in years) over which the excess volatility applies.
Volatility.ExcessVolatility	The excess volatility observed over a specified maturity.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash. For more information about volatility modeling, see the Volatility Modeling methodology.

Sigma [SVJD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion (SVJD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.
JumpReturn	The jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu + \sigma Z_i) - \text{JumpCompensator}\right\} - 1$$ where: • μ is the JumpMean parameter • σ is the JumpVolatility parameter • Z_i is a standard normal shock • n is the NumberOfJumps over the time step. The JumpCompensator is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\text{JumpCompensator} = \exp\left(\mu + \frac{1}{2}\sigma^2\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where *N* is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
JumpMean	The expected size of the log-jump.
ArrivalRate	The number of jumps expected per annum.
JumpVolatility	The volatility of the log-jump.
RiskNeutralArrivalRate	The number of jumps expected per annum, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpMean	The expected size of the log-jump, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpVolatility	The volatility of the log-jump size, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NumberOfSubdivisions input to the parent model (that is, ParentEquityAsset, ParentEquityAssetCorrelationModel, or Factor). Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description	Condition
MeanReversionRate	The rate of mean reversion of the stochastic variance process.	
Volatility	The volatility of the stochastic variance process.	
MeanReversionLevel	The mean reversion level of the stochastic variance process.	
InitialValue	The initial value of the stochastic variance process.	
Correlation	The correlation between the stochastic variance shock and the log return shock.	

Name	Description	Condition
RiskNeutralMeanReversionRate	The mean reversion rate of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMeanReversionLevel	The mean reversion level of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The instantaneous value of the variance.
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where *N* is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Sigma [SVJDTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model, where the parameters of both models are time-dependent.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{ \sum_{i=1}^{n} (\mu_J(t) + \sigma_J(t) Z_i) - \bar{\mu}(t) \right\} - 1$$ where: • $\mu_J(t)$ is the JumpMean parameter • $\sigma_J(t)$ is the JumpVolatility parameter • Z_i is a standard normal shock • n is the NumberOfJumps over the time step. The JumpCompensator $\mu_J(t)$ is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\bar{\mu}(t) = \exp\left(\mu_J(t) + \frac{1}{2}\sigma_J^2(t) \right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where: • *N* is the number of subdivisions • γ is a scaling parameter • V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N} \sqrt{V_{i-1}} Z_i}{\sqrt{\sum_{i=1}^{N} V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD TD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.
Parameters.ArrivalRate	The number of jumps expected per annum.
Parameters.JumpMean	The expected size of the log jump.
Parameters.JumpVolatility	The volatility of the log jump.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NrSubDivisions parameter. Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.
Parameters.VolatilityLevel	A time-dependent parameter which scales the stochastic variance process.
Parameters.MeanReversionRate	The rate of mean reversion of the stochastic variance process.
Parameters.MeanReversionLevel	The mean reversion level of the stochastic variance process.
Parameters.Volatility	The volatility of the stochastic variance process.
Parameters.Correlation	The correlation between the stochastic variance shock and the log return shock.
InitialValue	The initial value of the stochastic variance process.

Outputs

Name	Description
Value	The instantaneous value of the variance.
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where: • N is the number of subdivisions • γ is a scaling parameter • V_i is the instantaneous variance of the SVJD TD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N} \sqrt{V_{i-1}}\, Z_i}{\sqrt{\sum_{i=1}^{N} V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

4.1.6 ChildEquityAssetCorrelationModel

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Child equity assets are addable models. ChildEquityAssetCorrelationModel are similar to ChildEquityAssets except that they are directly correlated to other assets via the correlation matrix rather than indirectly using the EquityAssetFactors. For more information about ChildEquityAssets, see ChildEquityAsset. The returns of a Child equity asset are modeled according to exposure to its parent. *For example*, they can be used to represent individual stocks within an index (that is, the parent). The log-return is made up of the risk-free return, the exposure to its parent equity, a specific component, and an Itô term.

For more information about the differences between ChildEquityAsset and ChildEquityAssetCorrelationModel, see the Correlation of Equity Assets methodology.

Be aware of the naming convention for equity assets that enables them to be calibrated using standard calibration files.

Submodels

Name	Description
DividendYield	Models the dividend yield dynamics.
DividendPayoutRatio	Models the dividend payout ratio dynamics.

Name	Description
Alpha	The component of excess return not attributable to the parent asset. This submodel can be one of the following: • Alpha [FixedEquityReturn] • Alpha [TimeDependentEquityReturn]
Sigma	The volatility structure of the asset. Possible models: • Sigma [FixedVolatility] • Sigma [DeterministicVolatility] • Sigma [NPDeterministicVolatility] • Sigma [SVJD] • Sigma [SVJDTD]

Input variables

Name	Description
ParentAsset	The parent asset associated with this child asset.
Beta	The strength of exposure to the parent asset.
IntraSectorCorrelation	The correlation between assets within this sector or market.
NumberOfSubdivisions	The number of subintervals of each simulation time step. The number of subdivisions is used in models that use a Brownian bridge algorithm.
InitialIndexValue	The base value for index outputs.
IndividualRandomNumberScrambler	To adjust the random number stream for this model, enter a number > 0. The **IndividualRandomNumberScrambler** is appended to the model name, which the software uses to generate the random numbers. If this model is correlated with other models, then the random numbers in those models might change. For more information, see *Random Number Generation in the Scenario Generator: Seed-By-Trial Methodology*, available on the Customer Portal.

Outputs

Name	Description
TotalReturn	The total return earned on the asset over the time step. The output at time zero is meaningless and a default value of 0 is given. $\text{TotalReturn}(t) = \text{ExcessReturn}(t) + \text{CashTotalReturn}(t)$ Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.
AnnualisedTotalReturn	The annualized total return. $\text{AnnualisedTotalReturn}(t) = \text{AnnualisedIncomeReturn}(t) + \text{AnnualisedCapitalChange}(t)$
TotalReturnIndex	The total return index of the asset. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue.

Name	Description
ExcessReturn	The return earned on the asset in excess of the risk free return. Where the IncludeCashInTotalReturn is set to False, the ExcessReturn equals the TotalReturn.
ExcessReturnIndex	The excess return index of the asset. This output is calculated using the following equation: $$\begin{aligned}&\mathrm{ExcessReturnIndex}(t)\\&\quad=\mathrm{ExcessReturnIndex}(t-\Delta t)\times(1+\mathrm{ExcessReturn}(t))\end{aligned}$$ where ExcessReturnIndex(0) = 1.
RescaledTRI [StartVal]	The total return index of this asset, rescaled to the specific starting value.
CapitalChange	Price changes within the equity model are described by the output CapitalChange. Calculated using the equation: $$\begin{aligned}\mathrm{CapitalChange}(t)&=\frac{\mathrm{Price}(t)}{\mathrm{Price}(t-\Delta t)}-1\\&=\frac{1+\mathrm{TotalReturn}(t)}{1+\mathrm{DividendYield}(t)\times\Delta t}-1\end{aligned}$$ The output at time zero is meaningless and a default value of 0 is given.
AnnualisedCapitalChange	The annualized capital change. $$\mathrm{AnnualisedCapitalChange}(t)=(1+\mathrm{CapitalChange}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
CapitalIndex	The capital index of the asset $$\mathrm{CapitalIndex}(t)=\mathrm{CapitalIndex}(t-\Delta t)\times(1+\mathrm{CapitalChange}(t))$$ where CapitalIndex(0) = InitialIndexValue.
IncomeReturn	The total return minus the capital change.
AnnualisedIncomeReturn	The annualized income return. $$\mathrm{AnnualisedIncomeReturn}(t)=(1+\mathrm{IncomeReturn}(t))^{\frac{1}{\Delta t}}-1$$
IncomeIndex	The income index is calculated from the capital index and the dividend yield. $$\mathrm{IncomeIndex}(t)=\mathrm{CapitalIndex}(t)\times\mathrm{DividendYield}(t)$$
EarningsYield	The earnings yield of an asset: $$\mathrm{EarningsYield}(t)=\frac{\mathrm{DividendYield}(t)}{\mathrm{DividendPayout}(t)}$$
EarningsIndex	The earnings index of an asset. $$\begin{aligned}\mathrm{EarningsIndex}(t)&=\frac{\mathrm{IncomeIndex}(t)}{\mathrm{DividendPayout}(t)}\\&=\mathrm{CapitalIndex}(t)\times\mathrm{EarningsYield}(t)\end{aligned}$$
Volatility	The total volatility of the equity asset.
SpotVolatility[JumpContribution]	The spot volatility of the equity asset with option to include or exclude the contribution of jumps.
ZScore	The standardized return of an asset.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the base economy of the simulation for all trials and takes the average.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	Outputs time zero equity option prices and implied volatilities with option maturities corresponding to each time step. After selecting the test, enter the following values: • **OptionType**—**Call** or **Put**. • **StrikePrice**—The software calculates the strike of each contract as the time zero forward price for delivery of the total return index of the equity asset at the option maturity, multiplied by the **StrikePrice**. This method for calculating the strike is equivalent to selecting ForwardStrike2 in the corresponding EquityOptionImpliedVolatility output. • **IncludeAnalyticVol**—**True** or **False**. For equity assets where you have set the Sigma submodel to **DeterministicVolatility**, **FixedVolatility**, **NPDeterministicVolatility**, or **SVJD**, you can choose to calculate analytic implied volatilities at time zero.
Local Currency Equity Option Implied Volatility Test [OptionType, StrikePrice, IncludeAnalyticVol]	A local currency version of the Equity Option Implied Volatility Test described above. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

DividendYield

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend yield dynamics. Strong price returns tend to be followed by above average dividend growth, whereas equity falls tend to be followed by growth below average.

Input variables

Name	Description
Alpha	The rate of mean reversion.
Mu	The mean of the log of the dividend yield.
StartVal	The initial value of the dividend yield.
AssetReturnCorrelation	The correlation between changes in the dividend yield and the total return.
ZeroBoundFlag	Indicates whether a zero bound level is applied to the dividend yield.
ZeroBoundLevel	The level below which the dividend yield is forced to zero.

Outputs

Name	Description
Value	The dividend yield calculated over the time step. $$\begin{aligned}\text{DividendYield} &= \frac{1}{\Delta t}\frac{1+\text{TotalReturn}}{1+\text{CapitalChange}} - 1 \\ &= \frac{1}{\Delta t}\frac{\text{TotalReturn}-\text{CapitalChange}}{1+\text{CapitalChange}}\end{aligned}$$

DividendPayoutRatio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Models the dividend payout ratio dynamics.

Input variables

Name	Description
Alpha	The rate of mean reversion of the dividend payout ratio.
Sigma	The volatility of the dividend payout ratio.
Mu	The mean of the log of the dividend payout ratio.
StartVal	The initial value.
AssetReturnCorrelation	The correlation between changes in the dividend payout ratio and the total return.

Outputs

Name	Description
Value	The ratio of dividends to earnings.

Alpha [FixedEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A fixed equity return model.

Input variables

Name	Description
Value	The arithmetic risk premium from the asset-specific component.

Outputs

Name	Description
Value	The continuously compounded arithmetic expected risk premium associated with the specific component of the excess return.

Alpha [TimeDependentEquityReturn]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A time-dependent equity return model. Available only in real-world mode, that is, the simulation-level UseRiskNeutralValuation parameter is False.

Input variables

Name	Description
Value	The arithmetic expected risk premium from the asset-specific component, specified as piecewise constant continuously compounded rates applying during the given time intervals.
Smoothing	Select whether smoothing should be applied to the time-dependent risk premium.
InitialValue	The initial arithmetic risk premium from the asset-specific component. Used only when **Smoothing** is **True**.

Outputs

Name	Description
Value	The continuously compounded arithmetic expected risk premium associated with the specific component of the excess return.

Sigma [FixedVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A constant volatility model.

Input variables

Name	Description
Value	The value of the constant volatility that applies for the whole of the simulation.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is constant if the fixed volatility model is selected. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [DeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Time-varying deterministic volatility. For more information, see the Time-Varying Deterministic Volatility methodology.

Input variables

Name	Description
SigmaNought	The instantaneous volatility at time 0.
SigmaInf	The long-term instantaneous volatility.
Alpha	The rate of change of the instantaneous volatility.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Sigma [NPDeterministicVolatility]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Non-parametric deterministic volatility. For more information about non-parametric deterministic volatility, see the Non-Parametric Deterministic Volatility methodology.

Input variables

Name	Description
Volatility.Years	The time maturity (in years) over which the excess volatility applies.
Volatility.ExcessVolatility	The excess volatility observed over a specified maturity.

Outputs

Name	Description
Volatility	The volatility value. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash. For more information about volatility modeling, see the Volatility Modeling methodology.

Sigma [SVJD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion (SVJD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Name	Description
JumpReturn	The Jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu+\sigma Z_i) - \text{JumpCompensator}\right\} - 1$$ where: • μ is the JumpMean parameter • σ is the JumpVolatility parameter • Z_i is a standard normal shock • n is the NumberOfJumps over the time step. The JumpCompensator is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\text{JumpCompensator} = \exp\left(\mu + \frac{1}{2}\sigma^2\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where *N* is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
JumpMean	The expected size of the log-jump.
ArrivalRate	The number of jumps expected per annum.
JumpVolatility	The volatility of the log-jump.
RiskNeutralArrivalRate	The number of jumps expected per annum, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.
RiskNeutralJumpMean	The expected size of the log-jump, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Name	Description
RiskNeutralJumpVolatility	The volatility of the log-jump size, under the risk neutral measure. The software uses this parameter exclusively for implied volatility modeling when the UseRiskNeutralValuation is False.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NumberOfSubdivisions input to the parent model (that is, ParentEquityAsset, ParentEquityAssetCorrelationModel, or Factor). Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description	Condition
MeanReversionRate	The rate of mean reversion of the stochastic variance process.	
Volatility	The volatility of the stochastic variance process.	
MeanReversionLevel	The mean reversion level of the stochastic variance process.	
InitialValue	The initial value of the stochastic variance process.	
Correlation	The correlation between the stochastic variance shock and the log return shock.	
RiskNeutralMeanReversionRate	The mean reversion rate of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
RiskNeutralMeanReversionLevel	The mean reversion level of the underlying stochastic variance process, under the risk neutral measure.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.

Outputs

Name	Description
Value	The instantaneous value of the variance.
StandardisedVolatility	$$\text{StandardisedVolatility} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where N is the number of subdivisions, and V_i is the instantaneous variance of the SVJD process at micro-step i.
StandardisedShock	$$\text{StandardisedShock} = \frac{1}{(\text{StandardisedVolatility})}\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i\sqrt{\frac{1}{N}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Sigma [SVJDTD]

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) is a mixture of two well-known models, the Heston Stochastic Volatility (HSV) model and the Merton Jump Diffusion (MJD) model, where the parameters of both models are time-dependent.

The HSV model can be viewed as a two-factor model, where the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process. The HSV part of the model is used to model the continuous (diffusion) component of asset returns. In contrast, the MJD part is essentially used to model large sudden infrequent changes in asset prices that cannot be adequately described by the HSV model. Log-return associated with the Jump component is driven by a Compound Poisson Process (CPP).

Submodels

Name	Description
Jump	Log Normal Jump component, the log of the jump process is modeled using a compound Poisson process.
Variance	A one factor Cox-Ingersoll-Ross (CIR) model governing the variance dynamics.

Outputs

Name	Description
Volatility	The specific volatility of the equity asset. This value is not the same as the total volatility of the equity asset, or the volatility of the total return in excess of cash.

Name	Description
JumpReturn	The jump return is measure of asset return, due to using a jump process to describe asset return behavior. $$\text{JumpReturn} = \exp\left\{\sum_{i=1}^{n}(\mu_J(t) + \sigma_J(t)Z_i) - \bar{\mu}(t)\right\} - 1$$ where: • $\mu_J(t)$ is the JumpMean parameter • $\sigma_J(t)$ is the JumpVolatility parameter • Z_i is a standard normal shock • n is the NumberOfJumps over the time step. The JumpCompensator $\mu_J(t)$ is a term that ensures that the martingale property holds (that is, the expected jump return equals zero) and is defined as $$\bar{\mu}(t) = \exp\left(\mu_J(t) + \frac{1}{2}\sigma_J^2(t)\right) - 1$$
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N}V_{i-1}}$$ where: • *N* is the number of subdivisions • γ is a scaling parameter • V_i is the instantaneous variance of the SVJD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i}{\sqrt{\sum_{i=1}^{N}V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

Jump

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion (SVJD TD) model, the log-jump size is drawn from a normal distribution with mean equal to the JumpMean parameter.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.

Name	Description
Parameters.ArrivalRate	The number of jumps expected per annum.
Parameters.JumpMean	The expected size of the log jump.
Parameters.JumpVolatility	The volatility of the log jump.

Outputs

Name	Description
NumberOfJumps	The number of jumps that have occurred over the time step, where the jumps are realizations of a Poisson random variable that depends the ArrivalRate input parameter.
NumberOfMicroJumps [Index]	The number of jumps occurring in each subdivision of the time step. It is generated using a Brownian bridge algorithm, which is controlled by the NrSubDivisions parameter. Each micro-jump is a realization of a Poisson random variable.

Variance

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the Stochastic Volatility Jump Diffusion Time Dependent (SVJD TD) model, the volatility (strictly speaking variance) is described using a Cox-Ingersoll-Ross (CIR) square root process.

Input variables

Name	Description
Parameters.Years	Time Interval for which the associated jump parameter values apply.
Parameters.NrSubDivisions	Number of Brownian bridge subdivisions over the associated year interval.
Parameters.VolatilityLevel	A time-dependent parameter which scales the stochastic variance process.
Parameters.MeanReversionRate	The rate of mean reversion of the stochastic variance process.
Parameters.MeanReversionLevel	The mean reversion level of the stochastic variance process.
Parameters.Volatility	The volatility of the stochastic variance process.
Parameters.Correlation	The correlation between the stochastic variance shock and the log return shock.
InitialValue	The initial value of the stochastic variance process.

Outputs

Name	Description
Value	The instantaneous value of the variance.

Name	Description
StandardisedVolatility	$$\text{StandardisedVolatility} = \gamma(t)\sqrt{\frac{1}{N}\sum_{i=1}^{N} V_{i-1}}$$ where: • N is the number of subdivisions • γ is a scaling parameter • V_i is the instantaneous variance of the SVJD TD process at micro-step *i*.
StandardisedShock	$$\text{StandardisedShock} = \frac{\sum_{i=1}^{N}\sqrt{V_{i-1}}Z_i}{\sqrt{\sum_{i=1}^{N} V_{i-1}}}$$ where Z_i are the micro-shocks generated using the Brownian bridge algorithm.

4.2 FixedIncome

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Fixed Income assets can be of many different types, living in many different containers:

Containers

Name	Description
CashAssets	This container holds all the cash assets.
GenericBondPortfolios	This container holds generic bond portfolios including government, risky and municipal bond portfolios.
GenericIssuers	This container holds generic issuers of fixed income assets. These can only be generic pools of issuers.
SpecificIssuers	This container holds specific issuers including bond issuer, municipal issuer, and MBS issuer.

4.2.1 CashAssets

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This container holds cash assets.

Addable submodels

Name	Description
Cash	Cash assets produce returns linked to the nominal yield curve of the specified economy.

Cash

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Cash assets produce returns linked to the nominal yield curve of the specified economy.

Input variables

Name	Description
Economy	Defines the economy of the cash asset, and hence its dynamics are governed by the primary nominal yield curve of this economy.

Outputs

Name	Description
Price	The price of one unit of holding of the asset.
TotalReturn	The total return of cash over the time step. Calculated using the formula: $\text{TotalReturn}(t-\Delta t, t) = \exp(\text{ShortRate}(t-\Delta t, t) \times \Delta t) - 1.$
TotalReturnIndex	The total return index of an asset. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t-\Delta t, t) \times (1 + \text{TotalReturn}(t)).$ where TotalReturnIndex(0) = 1.
CapitalReturn	The change in Price from time step t-1 to t.
CapitalIndex	The capital index of an asset. $\text{CapitalIndex}(t) = \text{CapitalIndex}(t-\Delta t) \times (1 + \text{CapitalChange}(t))$ where CapitalIndex(0) = 1.0.
IncomeYield	The annualized Income return.
IncomeReturn	The total return minus the capital change.

4.2.2 GenericBondPortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In the model, generic bond portfolios can be used to describe a portfolio of bond assets with a homogeneous set of characteristics (coupon, term, credit quality, and so on). The application distinguishes between risk-free bond portfolios and credit-risky bond portfolios. You can also model generic municipal bonds and generic floating rate notes.

As an alternative to generic bond portfolios, you can use GenericIssuerPools and their GenericBondAssets as these have similar functionality.

Addable submodels

Name	Description
GovtGenericBondPortfolio	A portfolio asset composed of bonds that are not subject to risk of default.
RiskyGenericBondPortfolio	A portfolio asset composed of bonds that are subject to default.
GenericMunicipalBondPortfolio	A portfolio asset composed of municipal bonds subject to a tax rate.
GenericFRNPortfolio	A portfolio asset composed of floating rate notes.

GovtGenericBondPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Government generic bond portfolios containing bonds without risk of defaulting, that is, bonds with the government credit rating. It contains homogeneous portfolios of bonds, that is, same maturities, coupon, credit ratings, and seniority classes, although the portfolios can have different issuers.

An alternative to generic bond portfolios is to use GenericIssuerPools and their GenericBondAssets as these have similar functionality.

Input variables

Name	Description	Conditions
Strategy	Various investment strategies are permitted for the government generic bond portfolio. Valid values are: • **Fixed coupon and maturity**—Bonds are assumed to have a fixed coupon and maturity before each time increment in the model. The portfolio is rebalanced at the end of each time step back to the coupon and maturity specified. A **TermDeclineRate** parameter is available that allows the maturity of bond to which the portfolio is rebalanced to be reduced linearly over the course of the projection according to this rate (per annum). If the **TermDeclineRate** results in the bond rebalancing term being reduced to less than the model time step, the portfolio is assumed to be invested in cash. • **Fixed duration and convexity**—Bonds are assigned a coupon and maturity that is as consistent as possible with a fixed target duration and convexity. The bond coupon and maturity are derived once each year (that is, not necessarily each time	

Name	Description	Conditions
	step). Some combinations of duration and convexity inputs are not feasible. In particular, we must have $Convexity \geq Duration^2$ for reasonable coupons and maturities (that is, that reasonably represent the duration and convexity targets) to be derived and used. Where the targets are infeasible, the bonds model resembles a low coupon bond with maturity set equal to the duration target. Derivation of a maturity and coupon is not attempted for index-linked bonds. Instead, the maturity is set to the target duration and the coupon is set to zero. • **Buy and hold**—In this case, the term of the bond is not reset at any time, however, its credit rating is reset at the end of every model time step. This option achieves the same functionality as the **Fixed coupon and maturity** strategy with the **TermDeclineRate** set to **1**. After maturity the bonds are invested in "risky cash". That is, the value is rolled up according to short-term bond returns of the original input credit rating with no credit transitions. The CreditCost and Nominal outputs are not calculated for index linked bonds. • **Bond at par**—Bonds are assigned a coupon (given their maturity) so that the bond trades at par (that is, a price of 100) at the beginning of each time increment. The bond coupon is calculated and the maturity is reset at each time step. For index-linked bonds, the coupon used with this strategy is a continuously compounded spot rate derived from the risk-free default-free zero coupon bond price. • **Fixed duration and negative convexity**—Provides a means of approximating bond returns based only on the duration and convexity parameters together with the yield curve shift at the specified duration. This option is only an approximate calculation in which the maturity is the nearest time step and the coupon is zero, and it can have significant error relative to the exact return calculation. This strategy is not supported for index-linked bonds.	
Economy	The denomination of the issued bond.	
NominalYieldCurve	For nominal bonds, the nominal yield curve that you want to use for bond pricing. For **Index Linked**, the primary nominal yield curve is used.	Enabled only after you select an economy, and if **BondType** is **Nominal**.
InflationRates	The inflation model that you want to use to price bond assets and calculate inflation-linked increases. Bonds are priced using the real yield curve selected in the inflation model. The coupon and principal payments are inflated using the inflation index of the inflation model that you select.	Enabled only after you select an economy, and if **BondType** is **Index Linked**.
EquityAsset	Specifies the equity asset to provide the credit migration factor, which is used to drive the common undiversifiable component of credit transitions in the portfolio. If CreditMigrationFactorMethod is set to EquityZScore or StandardisedExcessLogReturn, then the correlation between the credit migration factor and the pricing yield curve is removed.	
BondType	The bonds can be nominal bonds or index-linked bonds. Nominal bonds are priced using the nominal yield curve, and index-linked bonds are priced using the real yield curve selected in the inflation model. Inflation is also considered when deriving the returns of index-linked bonds.	
NumberOfBonds	The number of bonds in the portfolio. We recommend using just a single bond in GovtGenericBondPortfolios because the bonds are not subject to default or migration.	
Coupon	The annual coupon rate of bonds in the portfolio.	

Name	Description	Conditions
Frequency	The number of coupon payments per year. If you leave this input blank, then the frequency is assumed to be 1/model time step, which can be useful when you are using variable length time steps. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **Frequency** of the generic bond portfolio to the nearest integer, such that the time between coupon payments is an integer multiple of the largest time step length in the simulation.	
Seniority	Seniority of the bonds in the portfolio. Since the bonds are not subject to default, this parameter is only included for backward compatibility.	
Term	The initial term (maturity) of the bonds. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **Term** of the generic bond portfolio to the nearest integer multiple of the largest time step length in the simulation.	
TermDeclineRate	The rate of term decline. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **TermDeclineRate** of the generic bond portfolio to the nearest integer multiple of the largest time step length in the simulation.	Used only if **Strategy** is **Fixed coupon and maturity**
Duration	The target duration, in years, of bonds in this portfolio.	Enabled only if **Strategy** is **Fixed duration and convexity** or **Fixed duration and negative convexity**
Convexity	The target convexity, in years^2, of bonds in this portfolio.	Enabled only if **Strategy** is **Fixed duration and convexity** or **Fixed duration and negative convexity**
InitialIndexValue	The base value for index outputs.	

Outputs

Name	Description
TotalReturn	The total return earned on an asset over the time interval. This is the sum of capital change and income return over this time period. $$\text{TotalReturn}(t) = \text{CapitalChange}(t) + \text{IncomeReturn}(t)$$ The output at time zero is meaningless and a value of 0 is given. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $$\text{TotalReturn}(t') = \frac{\text{TotalReturnIndex}(t')}{\text{TotalReturnIndex}(t' - \Delta t')} - 1$$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
AnnualisedTotalReturn	The annualized total return of this portfolio since the last output. $$\text{AnnualisedTotaReturn}(t) = \text{AnnualisedCapitalChange}(t) + \text{AnnualisedIncomeReturn}(t)$$

Name	Description
TotalReturnIndex	The total return index of an asset. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t-\Delta t) \times (1+\text{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue
RescaledTRI [StartVal]	The total return index (TRI) of this asset, rescaled by a designated value. This feature has been superseded by the InitialIndexValue parameter.
ExcessReturn	The return earned on the asset in excess of the risk free return.
ExcessReturnIndex	The excess return index of the asset. $\text{ExcessReturnIndex}(t) = \text{ExcessReturnIndex}(t-\Delta t) \times (1+\text{ExcessReturn}(t))$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in the value of the generic bond portfolio that has occurred over this time step. This is calculated using the portfolio value at the start of the time step, $\text{PortfolioValue}(t-\Delta t)$, and the portfolio value at the end of the time step before rebalancing, $\text{PortfolioValue}_{PreRebalancing}(t)$. That is: $\text{CapitalChange}(t) = \frac{\text{PortfolioValue}_{PreRebalancing}(t)}{\text{PortfolioValue}(t-\Delta t)} - 1$ $\text{PortfolioValue}(t)$ and $\text{PortfolioValue}_{PreRebalancing}(t)$ are defined in more detail below. The capital change at time zero is meaningless and a value of 0 is given. **Note** If the file output is not every time step, then it is calculated from the capital index as: $\text{CapitalChange}(t') = \frac{\text{CapitalIndex}(t')}{\text{CapitalIndex}(t'-\Delta t')} - 1$ where t' are the time steps that are actually output.
AnnualisedCapitalChange	The annualized capital change of this portfolio since the last output. $\text{AnnualisedCapitalChange}(t) = (1+\text{CapitalChange}(t))^{\frac{1}{\Delta t}} - 1$ where Δt is the time between outputs.
CapitalIndex	The capital index of the generic bond portfolio. This is an index of bond capital changes, that is, the total return excluding income. $\text{CapitalIndex}(t) = \text{CapitalIndex}(t-\Delta t) \times (1+\text{CapitalChange}(t))$ where CapitalIndex(0) = InitialIndexValue
IncomeReturn	The income return of the generic bond portfolio over this time period. This output is non-zero if and only if a coupon payment is received in this time period. The output is calculated as: $\text{IncomeReturn}(t) = \frac{\text{CouponIncome}(t)}{\text{PortfolioValue}(t-\Delta t)'}$ where CouponIncome represents the coupons received over the time step. Each coupon is rolled up to the end of the time step at the risk-free rate of return.
AnnualisedIncomeReturn	The annualized income return of this portfolio since the last output. $\text{AnnualisedIncomeReturn}(t) = (1+\text{IncomeReturn}(t))^{\frac{1}{\Delta t}} - 1$ where Δt is the time between outputs.
IncomeYield	The income yield of the generic bond portfolio. This output is calculated treating the Coupon input as if it were spread evenly over the whole year: $\text{IncomeYield}(t) = \frac{\text{Coupon} \times \Delta t}{\text{PortfolioValue}(t-\Delta t)}$

Name	Description
RedemptionYield	The gross redemption yield (also known as internal rate of return or yield to maturity) of the portfolio. It is the constant (discretely compounded) discount rate that would make the sum of discounted future cash flows equal to the present PortfolioValue. If the portfolio contains nominal bonds, then the yield is reported as a nominal yield. If the portfolio contains index-linked bonds, then the yield is reported as a real yield.
PortfolioValue	The value of a single unit of the portfolio (that is, one nominal unit) at this time step. This is defined as being the sum of discounted expected future cash flows, adjusted for default and any subsequent recovery. The portfolio value is reported after rebalancing at this time step has taken place. For example, for the "fixed coupon and maturity" strategy the maturity of the bonds has been reset to its initial value. In this case, the portfolio value is: $$\begin{aligned}\mathrm{PortfolioValue}(t) &= \mathrm{ZCBP}(\mathrm{Govt}, \mathrm{Maturity}, \mathrm{Seniority}, t) \\ &+ \sum_{i=0}^{n-1} \frac{c}{f} \times \mathrm{ZCBP}\left(\mathrm{Govt}, \mathrm{Maturity} - \frac{i}{f}, \mathrm{Seniority}, t\right)\end{aligned}$$ where: • c is the coupon. • f is the coupon frequency. • n is the number of coupon payments which is given by $n = \lceil \mathrm{Maturity} \times f \rceil$, where $\lceil \ \rceil$ indicates that it is rounded up to the nearest integer. The portfolio value immediately before rebalancing is required to determine the capital change. For the **Fixed coupon and maturity** strategy, the maturity has been shortened by one time step, Δt, and so the portfolio value is given by: $$\begin{aligned}\mathrm{PortfolioValue}_{PreRebalancing}(t) &= \mathrm{ZCBP}(\mathrm{Govt}, \mathrm{Maturity} - \Delta t, \mathrm{Seniority}, t) \\ &+ \sum_{i=0}^{n-1} \frac{c}{f} \times \mathrm{ZCBP}\left(\mathrm{Govt}, \mathrm{Maturity} - \Delta t - \frac{i}{f}, \mathrm{Seniority}, t\right).\end{aligned}$$
CreditCost	The component of return attributable to credit transitions (including defaults). It is the difference between the actual capital change earned on the portfolio, and the capital change that would have been earned if the portfolio had not experienced any change in credit rating or defaults. Since the bonds are not subject to default this parameter is only included for backward compatibility. This output is calculated as $\mathrm{CreditCost} = \mathrm{TotalReturn} - \mathrm{TransitionFreeReturn}$. **Note** This output is not calculated for index-linked bonds.
Nominal	An index representing the number of units of the portfolio held. At time 0, this value is set at 1. On subsequent time steps, the nominal value is calculated from the value of a single unit of the portfolio immediately before and after the rebalancing of the portfolio. That is, the rebalancing mimics the process of selling the existing bonds and buying new bonds with specific features. It is likely that we are able to buy more (or less) of the new bonds than we had of the existing bonds, and this is reflected in the Nominal output. **Note** This output is not calculated for index-linked bonds.
NumUpgrades	The number of upgrades over the previous time step. **Note** Because the bonds are not subject to default, this output is included only for backward compatibility.
NumDowngrades	The number of downgrades over the previous time step. **Note** Because the bonds are not subject to default, this output is included only for backward compatibility.
NumDefaults	The number of defaults over the previous time step.

Name	Description
	Note Because the bonds are not subject to default, this output is included only for backward compatibility.
NumberOfBonds [CreditClass]	The number of bonds of the generic bond portfolio that are in the specified credit class at the end of the time step. **Note** Because the bonds are not subject to default, this output is included only for backward compatibility.
PortfolioProportion [CreditClass]	The proportion of the portfolio that is in the specified credit class at the end of each time step. **Note** Because the bonds are not subject to default, this output is included only for backward compatibility.
Term	The remaining term of the bond from the current time step.
Coupon	The actual coupon to be used over the next time step.
Duration	The duration of the bond portfolio. $$\mathrm{D}(t) = \frac{1}{P(t)} \times \left[(T-t) \times Z(C, T-t, S, t) + \sum_{i=0}^{n-1} \frac{c}{f} \times \left(T - t - \frac{i}{f} \right) \times Z\left(C, T - t - \frac{i}{f}, S, t \right) \right]$$ where: $P(t)$ is the current portfolio value (in the currency of the bond), calculated post-rebalancing. Z is the price of a zero-coupon bond, expressed as $Z(creditclass, term, seniority, t)$, of the specified nominal (if Type = nominal) or real (if Type = index-linked) yield curve of the economy of the portfolio. T is the time at which the bond matures. C is the credit class. S is the seniority. c is the coupon rate. f is the coupon frequency per annum. n is the number of remaining coupon payments (rounded up to the nearest integer), where $n = [(T-t) \times f]$.
Convexity	The convexity of the bond portfolio. $$\mathrm{Convexity}(t) = \frac{1}{P(t)} \times \left[(T-t)^2 \times Z(C, T-t, S, t) + \sum_{i=0}^{n-1} \frac{c}{f} \times \left(T - t - \frac{i}{f} \right)^2 \times Z\left(C, T - t - \frac{i}{f}, S, t \right) \right]$$ where: $P(t)$ is the current portfolio value (in the currency of the bond), calculated post-rebalancing. Z is the price of a zero-coupon bond, expressed as $Z(creditclass, term, seniority, t)$, of the specified nominal (if Type = nominal) or real (if Type = index-linked) yield curve of the economy of the portfolio. T is the time at which the bond matures. C is the credit class. S is the seniority. c is the coupon rate. f is the coupon frequency per annum. n is the number of remaining coupon payments (rounded up to the nearest integer), where $n = [(T-t) \times f]$.

Name	Description
	Note This formula is not compatible with bond portfolios for which the Strategy parameter is set to **Fixed duration and negative convexity**. A convexity of 0 is output for portfolios following this strategy.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index for all trials and takes the average. Index-Linked bonds fail Martingale tests when using InflationPlus unless the correlation between inflation shock and real rates shocks is zero. For more information about the reasons for the Martingale Tests failing, see the Inflation Modeling methodology.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Option Implied Volatility Test	Allows you to compare option prices implied by the simulation with market implied volatilities.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

RiskyGenericBondPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Generic bond portfolios containing bonds with any credit rating. It contains homogeneous portfolios of bonds, that is, same maturities, coupon, credit ratings, and seniority classes, although the portfolios can have different issuers.

An alternative to generic bond portfolios is to use GenericIssuerPools and their GenericBondAssets as these have similar functionality. In particular, they allow the modeling of a true Buy and Hold strategy, in which the credit class is not rebalanced.

Note The software prices credit-risky bonds analytically under the assumption that credit rating transitions are independent of the cash total return index of the pricing yield curve. Martingale tests therefore only pass if you set up the **CorrelationMatrix** accordingly.

Input variables

Name	Description	Conditions
Strategy	Various investment strategies are permitted for the government generic bond portfolio. Valid values are: • **Fixed coupon and maturity**—Bonds are assumed to have a fixed coupon and maturity before each time increment in the model. The portfolio is rebalanced at the end of each time step back to the coupon and maturity specified. A **TermDeclineRate** parameter is available that allows the maturity of bond to which the portfolio is rebalanced to be reduced linearly over the course of the projection	

Name	Description	Conditions
	according to this rate (per annum). If the **TermDeclineRate** results in the bond rebalancing term being reduced to less than the model time step, the portfolio is assumed to be invested in cash. • **Fixed duration and convexity**—Bonds are assigned a coupon and maturity that is as consistent as possible with a fixed target duration and convexity. The bond coupon and maturity are derived once each year (that is, not necessarily each time step). Some combinations of duration and convexity inputs are not feasible. In particular, we must have $Convexity \geq Duration^2$ for reasonable coupons and maturities (that is, that reasonably represent the duration and convexity targets) to be derived and used. Where the targets are infeasible, the bonds model resembles a low coupon bond with maturity set equal to the duration target. Derivation of a maturity and coupon is not attempted for index-linked bonds. Instead, the maturity is set to the target duration and the coupon is set to zero. • **Buy and hold**—In this case, the term of the bond is not reset at any time, however, its credit rating is reset at the end of every model time step. This achieves the same functionality as the **Fixed coupon and maturity** strategy with the **TermDeclineRate** set to **1**. After maturity the bonds are invested in "risky cash". That is, the value is rolled up according to short-term bond returns of the original input credit rating with no credit transitions. The CreditCost and Nominal outputs are not calculated for index linked bonds. • **Bond at par**—Bonds are assigned a coupon (given their maturity) so that the bond trades at par (that is, a price of 100) at the beginning of each time increment. The bond coupon is calculated and the maturity is reset at each time step. For index-linked bonds, the coupon used with this strategy is a continuously compounded spot rate derived from the risk-free default-free zero coupon bond price. • **Fixed duration and negative convexity**—Provides a means of approximating bond returns based only on the duration and convexity parameters together with the yield curve shift at the specified duration. This is only an approximate calculation in which the maturity is the nearest time step and the coupon is zero, and it can have significant error relative to the exact return calculation. This strategy is not supported for index-linked bonds.	
Economy	The denomination of the issued bond.	
NominalYieldCurve	For nominal bonds, the nominal yield curve that you want to use for bond pricing. For **Index Linked**, the primary nominal yield curve is used.	Enabled only after you select an economy, and if **BondType** is **Nominal**
InflationRates	The inflation model that you want to use to price bond assets and calculate inflation-linked increases. Bonds are priced using the real yield curve selected in the inflation model. The coupon and principal payments are inflated using the inflation index of the inflation model that you select.	Enabled only after you select an economy, and if **BondType** is **Index Linked**.
CreditModel	The model that the software uses to determine credit rating transition probabilities for the issuers in this risky generic bond portfolio.	
EquityAsset	Specify the equity asset that you want to use to provide the credit migration factor, which is the common undiversifiable component of credit rating transitions in the bond portfolio. If CreditMigrationFactorMethod is set to EquityZScore or StandardisedExcessLogReturn, then the correlation between the credit migration factor and the pricing yield curve is removed.	
CreditClass	The credit class of bonds within this risky generic bond portfolio.	
BondType	The bonds can be nominal bonds or index-linked bonds. Nominal bonds are priced using the nominal yield curve, and index-linked bonds are priced using the real yield	

Name	Description	Conditions
	curve selected in the inflation model. Inflation is also considered when deriving the returns of index-linked bonds.	
NumberOfBonds	The number of bonds in the portfolio. We recommend using multiple bonds (*for example*, 50–100) in RiskyGenericBondPortfolios to get a reasonable representation of the spread of credit transitions. Increasing the number of bonds increases the simulation time slightly.	
InfiniteNumberOfBonds	To set up a run with a (theoretical) infinite number of bonds, select **True**. If you choose to use an infinite number of bonds, the software ignores the value in the **NumberOfBonds** parameter. **Note** To avoid a potential performance overhead, we recommend that you set the **NumberOfBonds** parameter to **1** before setting the **InfiniteNumberOfBonds** parameter to **True**. When the **InfiniteNumberOfBonds** parameter is **True** , the **NumberOfBonds** parameter has no effect on any output values.	
Coupon	The annual coupon rate of bonds in the portfolio.	
Frequency	The number of coupon payments per year. If you leave this input blank, then the frequency is assumed to be 1/model time step, which can be useful when you are using variable length time steps. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **Frequency** of the generic bond portfolio to the nearest integer, such that the time between coupon payments is an integer multiple of the largest time step length in the simulation.	
Term	The initial term (maturity) of the bonds. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **Term** of the generic bond portfolio to the nearest integer multiple of the largest time step length in the simulation.	
TermDeclineRate	The rate of term decline. ESG only: If you set the simulation-level flag **EnsureValidBondTerm** to **True**, then the software adjusts the **TermDeclineRate** of the generic bond portfolio to the nearest integer multiple of the largest time step length in the simulation.	Used only if **Strategy** is **Fixed coupon and maturity**
Seniority	Seniority of the bonds in the portfolio, which is used when defining default recovery rates.	
InitialIndexValue	The base value for index outputs.	
Duration	The target duration, in years, of bonds in this portfolio.	Enabled only if **Strategy** is **Fixed duration and convexity** or **Fixed duration and negative convexity**
Convexity	The target convexity, in years^2, of bonds in this portfolio.	Enabled only if **Strategy** is **Fixed duration and convexity** or **Fixed duration and negative convexity**

Outputs

Name	Description
TotalReturn	The total return earned on an asset over the time interval. This is the sum of capital change and income return over this time period. $\mathrm{TotalReturn}(t) = \mathrm{CapitalChange}(t) + \mathrm{IncomeReturn}(t)$ The output at time zero is meaningless and a value of 0 is given. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $\mathrm{TotalReturn}(t') = \frac{\mathrm{TotalReturnIndex}(t')}{\mathrm{TotalReturnIndex}(t' - \Delta t')} - 1$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
AnnualisedTotalReturn	The annualized total return of this portfolio since the last output. $\mathrm{AnnualisedTotaReturn}(t) = \mathrm{AnnualisedCapitalChange}(t) + \mathrm{AnnualisedIncomeReturn}(t)$
TotalReturnIndex	The total return index of an asset. $\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t - \Delta t) \times (1 + \mathrm{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue
RescaledTRI [StartVal]	The total return index (TRI) of this asset, rescaled by a designated value. This feature has been superseded by the InitialIndexValue parameter.
ExcessReturn	The return earned on the asset in excess of the risk free return.
ExcessReturnIndex	The excess return index of the asset. $\mathrm{ExcessReturnIndex}(t) = \mathrm{ExcessReturnIndex}(t - \Delta t) \times (1 + \mathrm{ExcessReturn}(t))$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in the value of the generic bond portfolio that has occurred over this time step. This is calculated using the portfolio value at the start of the time step, $\mathrm{PortfolioValue}(t - \Delta t)$, and the portfolio value at the end of the time step before rebalancing, $\mathrm{PortfolioValue}_{PreRebalancing}(t)$. That is: $\mathrm{CapitalChange}(t) = \frac{\mathrm{PortfolioValue}_{PreRebalancing}(t)}{\mathrm{PortfolioValue}(t - \Delta t)} - 1$ $\mathrm{PortfolioValue}(t)$ and $\mathrm{PortfolioValue}_{PreRebalancing}(t)$ are defined in more detail below. The capital change at time zero is meaningless and a value of 0 is given. **Note** If the file output is not every time step, then it is calculated from the capital index as: $\mathrm{CapitalChange}(t') = \frac{\mathrm{CapitalIndex}(t')}{\mathrm{CapitalIndex}(t' - \Delta t')} - 1$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
AnnualisedCapitalChange	The annualized capital change of this portfolio since the last output. $\mathrm{AnnualisedCapitalChange}(t) = (1 + \mathrm{CapitalChange}(t))^{\frac{1}{\Delta t}} - 1$ where Δt is the time between outputs.
CapitalIndex	The capital index of the generic bond portfolio. This output is an index of bond capital changes, that is, the total return excluding income. $\mathrm{CapitalIndex}(t) = \mathrm{CapitalIndex}(t - \Delta t) \times (1 + \mathrm{CapitalChange}(t))$ where CapitalIndex(0) = InitialIndexValue

Name	Description
IncomeReturn	The income return of the generic bond portfolio over this time period. This output is non-zero if and only if a coupon payment is received in this time period. The output is calculated as: $$\text{IncomeReturn}(t) = \frac{\text{CouponIncome}(t)}{\text{PortfolioValue}(t' - \Delta t')}$$ where CouponIncome represents the coupons received since the last time step output. Each coupon is rolled up from the point it is received to the output time step at the credit risky rate of return; defaults are simulated at the end of each time step. Coupons from defaulted bonds are reduced by the recovery rate corresponding to the seniority of the bond.
AnnualisedIncomeReturn	The annualized income return of this portfolio since the last output. $$\text{AnnualisedIncomeReturn}(t) = (1 + \text{IncomeReturn}(t))^{\frac{1}{\Delta t}} - 1$$ where Δt is the time between outputs.
IncomeYield	The income yield of the generic bond portfolio. This output is calculated treating the Coupon input as if it were spread evenly over the period: $$\text{IncomeYield}(t) = \frac{\text{Coupon} \times \Delta t}{\text{PortfolioValue}(t - \Delta t)}$$
RedemptionYield	The gross redemption yield (also known as internal rate of return or yield to maturity) of the portfolio. It is the constant (discretely compounded) discount rate that would make the sum of discounted future cash flows equal to the present PortfolioValue. If the portfolio contains nominal bonds, then the yield is reported as a nominal yield. If the portfolio contains index-linked bonds, then the yield is reported as a real yield.
PortfolioValue	The value of a single unit of the portfolio (that is, one nominal unit) at this time step. This is defined as being the sum of discounted expected future cash flows, adjusted for default and any subsequent recovery. The portfolio value is reported after rebalancing at this time step has taken place. *For example*, for the **Fixed coupon and maturity** strategy the maturity of the bonds has been reset to its initial value. In this case, the portfolio value is: $$\begin{aligned}\text{PortfolioValue}(t) &= \text{ZCBP}(\text{CreditClass}, \text{Maturity}, \text{Seniority}, t) \\ &+ \sum_{i=0}^{n-1} \frac{c}{f} \times \text{ZCBP}\left(\text{CreditClass}, \text{Maturity} - \frac{i}{f}, \text{Seniority}, t\right)\end{aligned}$$ with c being the coupon, f being the coupon frequency, and n being the number of coupon payments which is given by $n = \lceil \text{Maturity} \times f \rceil$, where $\lceil\ \rceil$ indicates that it is rounded up to the nearest integer. The portfolio value immediately before rebalancing is required to determine the capital change. For the **Fixed coupon and maturity** strategy, the portfolio is composed of bonds whose maturity has been shortened by one time step, Δt , and the bonds have a range of credit classes. In this case, the portfolio value is then given by: $$\begin{aligned}&\text{PortfolioValue}_{PreRebalancing}(t) \\ &= \sum_j \text{PortfolioProportion}_{PreRebalancing}\left(\text{CreditClass}_j, t\right) \\ &\times \left[\begin{array}{c}\text{ZCBP}\left(\text{CreditClass}_j, \text{Maturity} - \Delta t, \text{Seniority}, t\right) \\ + \sum_{i=0}^{n-1} \frac{c}{f} \times \text{ZCBP}\left(\text{CreditClass}_j, \text{Maturity} - \Delta t - \frac{i}{f}, \text{Seniority}, t\right)\end{array}\right] \\ &+ \text{PortfolioProportion}_{PreRebalancing}(Default, t) \times \text{RecoveryRate}(\text{Seniority}) \\ &\times \left[\begin{array}{c}\text{ZCBP}(\text{Govt}, \text{Maturity} - \Delta t, \text{Seniority}, t) \\ + \sum_{i=0}^{n-1} \frac{c}{f} \times \text{ZCBP}\left(\text{Govt}, \text{Maturity} - \Delta t - \frac{i}{f}, \text{Seniority}, t\right)\end{array}\right]\end{aligned}$$ where the summation over j is a summation over all credit classes AAA, AA, …, CCC.

Name	Description
TransitionFreeReturn	The component of return that cannot be attributed to credit transitions (or defaults) for nominal bond portfolios. It is the capital change that would have been earned if the portfolio had not experienced any change in credit rating or defaults. For index-linked bond portfolios, this value returns 0.
InterestRateReturn	The component of the return attributable to changes in the interest rate for nominal bond portfolios. That is, credit spreads are assumed to be unchanged from the previous time step, and credit migrations and defaults have not occurred. For index-linked bond portfolios, this value returns 0.
CreditCost	The component of return attributable to credit transitions (including defaults) for nominal bond portfolios. It is the difference between the actual capital change earned on the portfolio, and the capital change that would have been earned if the portfolio had not experienced any change in credit rating or defaults. This output is calculated as $\mathrm{CreditCost} = \mathrm{TotalReturn} - \mathrm{TransitionFreeReturn}$. For index-linked bond portfolios, this value returns 0.
DefaultReturn	The component of the return attributable to bond defaults for nominal bond portfolios. For index-linked bond portfolios, this value returns 0.
Nominal	An index representing the number of units of the portfolio held. At time 0, this value is set at 1. On subsequent time steps, the nominal value is calculated from the value of a single unit of the portfolio immediately before and after the rebalancing of the portfolio. **Note** This output is not calculated for index-linked bonds.
NumUpgrades	The number of upgrades over the previous time step.
NumDowngrades	The number of downgrades over the previous time step.
NumDefaults	The number of defaults over the previous time step.
NumberOfBonds [CreditClass]	The number of bonds of the generic bond portfolio that are in the specified credit class at the end of the time step immediately before rebalancing.
PortfolioProportion [CreditClass]	The proportion of the portfolio of the specified credit class at the end of the time step immediately before rebalancing. Calculated using the equation: $\mathrm{PortfolioProportion}(\mathrm{CreditClass}, t) = \dfrac{\mathrm{NumberOfBonds}(\mathrm{CreditClass}, t)}{\mathrm{NumberOfBonds}}$
Coupon	The actual coupon to be used over the next time step.
Term	The remaining term of the bond from the current time step.

Name	Description
Duration	The duration of the bond portfolio. $$\mathrm{D}(t) = \frac{1}{P(t)} \times \left[(T-t) \times Z(C, T-t, S, t) + \sum_{i=0}^{n-1} \frac{c}{f} \times \left(T - t - \frac{i}{f} \right) \times Z\left(C, T - t - \frac{i}{f}, S, t \right) \right]$$ where: $P(t)$ is the current portfolio value (in the currency of the bond), calculated post-rebalancing. Z is the price of a zero-coupon bond, expressed as $Z(creditclass, term, seniority, t)$, of the specified nominal (if Type = nominal) or real (if Type = index-linked) yield curve of the economy of the portfolio. T is the time at which the bond matures. C is the credit class. S is the seniority. c is the coupon rate. f is the coupon frequency per annum. n is the number of remaining coupon payments (rounded up to the nearest integer), where $n = [(T-t) \times f]$.
Convexity	The convexity of the bond portfolio. $$\mathrm{Convexity}(t) = \frac{1}{P(t)} \times \left[(T-t)^2 \times Z(C, T-t, S, t) + \sum_{i=0}^{n-1} \frac{c}{f} \times \left(T - t - \frac{i}{f} \right)^2 \times Z\left(C, T - t - \frac{i}{f}, S, t \right) \right]$$ where: $P(t)$ is the current portfolio value (in the currency of the bond), calculated post-rebalancing. Z is the price of a zero-coupon bond, expressed as $Z(creditclass, term, seniority, t)$, of the specified nominal (if Type = nominal) or real (if Type = index-linked) yield curve of the economy of the portfolio. T is the time at which the bond matures. C is the credit class. S is the seniority. c is the coupon rate. f is the coupon frequency per annum. n is the number of remaining coupon payments (rounded up to the nearest integer), where $n = [(T-t) \times f]$. **Note** This formula is not compatible with bond portfolios for which the Strategy parameter is set to **Fixed duration and negative convexity**. A convexity of 0 is output for portfolios following this strategy.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index for all trials and takes the average. Index-Linked bonds fail Martingale tests when using InflationPlus unless the correlation between inflation shock and real rates shocks is zero.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.

Name	Description
Option Implied Volatility Test	Allows you to compare option prices implied by the simulation with market implied volatilities.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

GenericMunicipalBondPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Generic municipal bond portfolios containing bonds with any credit rating. It contains homogeneous portfolios of bonds, that is, same maturities, coupon, credit ratings, and seniority classes, although the portfolios can have different issuers.

Municipal bonds do not pass martingale tests.

Input variables

Name	Description	Condition
Strategy	Various investment strategies are permitted for the notional bond portfolio. Valid values are: • **Fixed coupon and maturity**—Bonds are assumed to have a fixed coupon and maturity before each time increment in the model. The portfolio is rebalanced at the end of each time step back to the coupon and maturity specified. A **TermDeclineRate** parameter is available that allows the maturity of bond to which the portfolio is rebalanced to be reduced linearly over the course of the projection according to this rate (per annum). If the **TermDeclineRate** results in the bond rebalancing term being reduced to less than the model time step, the portfolio is assumed to be invested in cash. • **Buy and hold**—In this case, the bonds' term is not rebalanced over time. However, its credit rating is still rebalanced at the end of every model time step. This achieves the same functionality as Fixed coupon and maturity with **TermDeclineRate** set to 1. This is not implemented for index-linked bonds. • **Bond at par**—Bonds are assigned a coupon (given their maturity) so that, at the beginning of each time increment, the bond trades at par (that is, a price of 100). The bond coupon and maturity are reset once each year.	
MunicipalSpread	The municipal spread that the software uses for bond pricing. The **Economy** of the **MunicipalSpread** determines the denomination of the issued bond.	
EquityAsset	The equity asset that the software uses to calculate the credit migration factor, which drives the common undiversifiable component of credit rating transitions in the bond portfolio. If CreditMigrationFactorMethod is set to EquityZScore or StandardisedExcessLogReturn, then the correlation between the credit migration factor and the pricing yield curve is removed.	
CreditClass	Select from **Govt** through to **CCC** bonds.	
BondType	Currently the ESG is only configured to model nominal municipal bond portfolios.	
NumberOfBonds	The number of bonds in the portfolio.	

Name	Description	Condition
Coupon	The annual coupon rate of bonds in the portfolio. The coupon frequency is assumed to be 1/model time step.	
Frequency	The number of coupon payments per year. If you leave this input blank, then the frequency is assumed to be 1/model time step, which can be useful when you are using variable length time steps. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **Frequency** of the generic bond portfolio to the nearest integer, such that the time between coupon payments is an integer multiple of the largest time step length in the simulation.	
Term	The initial term (maturity) of the bonds. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **Frequency** of the generic bond portfolio to the nearest integer, such that the time between coupon payments is an integer multiple of the largest time step length in the simulation.	
TermDeclineRate	The rate of term decline. ESG only: If you set the simulation-level **EnsureValidBondTerm** to **True**, then the software adjusts the **Frequency** of the generic bond portfolio to the nearest integer, such that the time between coupon payments is an integer multiple of the largest time step length in the simulation.	Used only if **Strategy** is **Fixed coupon and maturity**.
Seniority	Seniority of the bonds in the portfolio. This input is linked to a table of expected recovery rates associated with the economy of the portfolio.	
InitialIndexValue	The base value for index outputs.	

Outputs

Name	Description
TotalReturn	The total return earned on an asset over the time interval. This is the sum of capital change and income return over this time period. $\text{TotalReturn}(t) = \text{CapitalChange}(t) + \text{IncomeReturn}(t)$ The output at time zero is meaningless and a value of 0 is given. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $\text{TotalReturn}(t') = \frac{\text{TotalReturnIndex}(t')}{\text{TotalReturnIndex}(t' - \Delta t')} - 1$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
AnnualisedTotalReturn	The annualized total return of this portfolio since the last output. $\text{AnnualisedTotaReturn}(t) = \text{AnnualisedCapitalChange}(t) + \text{AnnualisedIncomeReturn}(t)$
TotalReturnIndex	The total return index of an asset. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue
RescaledTRI [StartVal]	The total return index (TRI) of this asset, rescaled by a designated value. This feature has been superseded by the InitialIndexValue parameter.
ExcessReturn	The return earned on the asset in excess of the risk free return.

Name	Description
ExcessReturnIndex	The excess return index of the asset. $\text{ExcessReturnIndex}(t) = \text{ExcessReturnIndex}(t - \Delta t) \times (1 + \text{ExcessReturn}(t))$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in the value of the generic bond portfolio that has occurred over this time step. This is calculated using the portfolio value at the start of the time step, and the portfolio value at the end of the time step before rebalancing. The capital change at time zero is meaningless and a value of 0 is given. **Note** If the file output is not every time step, then it is calculated from the capital index as: $\text{CapitalChange}(t') = \frac{\text{CapitalIndex}(t')}{\text{CapitalIndex}(t' - \Delta t')} - 1$ where t' are the time steps that are actually output.
AnnualisedCapitalChange	The annualized capital change of this portfolio since the last output. $\text{AnnualisedCapitalChange}(t) = (1 + \text{CapitalChange}(t))^{\frac{1}{\Delta t}} - 1$ where Δt is the time between outputs.
CapitalIndex	The capital index of the generic bond portfolio. This output is an index of bond capital changes, that is, the total return excluding income. $\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$ where CapitalIndex(0) = InitialIndexValue
IncomeReturn	The income return of the generic bond portfolio over this time period. This output is non-zero if and only if a coupon payment is received in this time period. The output is calculated as: $\text{IncomeReturn}(t) = \frac{\text{CouponIncome}(t)}{\text{PortfolioValue}(t - \Delta t)'}$ where CouponIncome represents the coupons received over the time step. Each coupon is rolled up to the end of the time step at the credit risky rate of return; defaults are simulated at the end of each time step. Coupons from defaulted bonds are reduced by recovery rate corresponding to the seniority of the bond.
AnnualisedIncomeReturn	The annualized income return of this portfolio since the last output. $\text{AnnualisedIncomeReturn}(t) = (1 + \text{IncomeReturn}(t))^{\frac{1}{\Delta t}} - 1$ where Δt is the time between outputs.
IncomeYield	The income yield of the generic bond portfolio. This output is calculated treating the Coupon input as if it were spread evenly over the whole year: $\text{IncomeYield}(t) = \frac{\text{Coupon} \times \Delta t}{\text{PortfolioValue}(t - \Delta t)}$
RedemptionYield	The gross redemption yield (also known as internal rate of return or yield to maturity) of the portfolio. It is the constant (discretely compounded) discount rate that would make the sum of discounted future cash flows equal to the present PortfolioValue.
PortfolioValue	The value of a single bond in the portfolio (per unit nominal) at this time step. This output is defined as being the sum of discounted expected future cash flows, adjusted for tax, default, and any subsequent recovery.
TransitionFreeReturn	The component of return that cannot be attributed to credit transitions (or defaults). It is the capital change that would have been earned if the portfolio had not experienced any change in credit rating or defaults.

Name	Description
CreditCost	The component of return attributable to credit transitions. It is the difference between the actual annually compounded return earned on the portfolio, and the return that would have been earned if the portfolio had not experienced any change in credit rating. This output is calculated as $\mathrm{CreditCost} = \mathrm{TotalReturn} - \mathrm{TransitionFreeReturn}$.
Nominal	The nominal value of each bond held. At time 0, this value is set at 1. On subsequent time steps, the nominal value is calculated from value of the bond portfolio after the rebalancing of the portfolio holdings.
NumUpgrades	The number of upgrades over the previous time step.
NumDowngrades	The number of downgrades over the previous time step.
NumDefaults	The number of defaults over the previous time step.
NumberOfBonds [CreditClass]	The number of bonds in the generic municipal bond portfolio of the specified credit class.
PortfolioProportion [CreditClass]	The proportion of the portfolio of the specified credit class at the end of the time step immediately before rebalancing. Calculated using the equation: $$\mathrm{PortfolioProportion}(\mathrm{CreditClass}, t) = \frac{\mathrm{NumberOfBonds}(\mathrm{CreditClass}, t)}{\mathrm{NumberOfBonds}}$$
Duration	The duration of the bond portfolio. $$\mathrm{D}(t) = \frac{1}{P(t)} \times \left[(T-t) \times Z(C, T-t, S, t) + \sum_{i=0}^{n-1} \frac{c}{f} \times \left(T - t - \frac{i}{f}\right) \times Z\left(C, T - t - \frac{i}{f}, S, t\right)\right]$$ where: $P(t)$ is the current portfolio value (in the currency of the bond), calculated post-rebalancing. Z is the price of a zero-coupon bond, expressed as $Z(creditclass, term, seniority, t)$, of the specified nominal (if Type = nominal) or real (if Type = index-linked) yield curve of the economy of the model specified in the **MunicipalSpread** parameter. T is the time at which the bond matures. C is the credit class. S is the seniority. c is the coupon rate. f is the coupon frequency per annum. n is the number of remaining coupon payments (rounded up to the nearest integer), where $n = [(T-t) \times f]$.

Name	Description
Convexity	The convexity of the bond portfolio. $$\text{Convexity}(t) = \frac{1}{P(t)} \times \left[(T-t)^2 \times Z(C, T-t, S, t) + \sum_{i=0}^{n-1} \frac{c}{f} \times \left(T - t - \frac{i}{f} \right)^2 \times Z\left(C, T - t - \frac{i}{f}, S, t \right) \right]$$ where: $P(t)$ is the current portfolio value (in the currency of the bond), calculated post-rebalancing. Z is the price of a zero-coupon bond, expressed as $Z(creditclass, term, seniority, t)$, of the specified nominal (if Type = nominal) or real (if Type = index-linked) yield curve of the economy of the model specified in the **MunicipalSpread** parameter. T is the time at which the bond matures. C is the credit class. S is the seniority. c is the coupon rate. f is the coupon frequency per annum. n is the number of remaining coupon payments (rounded up to the nearest integer), where $n = [(T-t) \times f]$.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index for all trials and takes the average. If the municipal spread tax rates are non-zero, municipal bonds do not pass martingale tests.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Option Implied Volatility Test	Allows you to compare option prices implied by the simulation with market implied volatilities.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

GenericFRNPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Input variables

Name	Description
Strategy	The investment strategy for this portfolio. • **MarginAtPar** - Notes are assigned a margin (given their maturity) so that the note trades at par (that is, a price of 100) at the beginning of each time increment. The margin is calculated and the maturity and credit class are reset at each time step.

Name	Description
Economy	The economy in which the note is denominated.
PricingCurve	The yield curve used to discount the cash flows in the pricing calculation.
CouponCurve	The yield curve used to obtain the coupon rate at each reset date.
EquityAsset	The equity asset that the software uses to calculate the credit migration factor, which drives the common undiversifiable component of credit rating transitions in the bond portfolio. If CreditMigrationFactorMethod is set to EquityZScore or StandardisedExcessLogReturn, then the correlation between the credit migration factor and the pricing yield curve is removed.
CreditModel	The model that the software uses to determine credit rating transition probabilities for the issuers in this generic FRN portfolio.
CreditClass	The credit class of notes within this portfolio.
NumberOfIssuers	The number of issuers of notes in this portfolio, with each issuer responsible for issuing one note. Each distinct issuer could transition credit class, or default, in each time step. Only used when InfiniteNumberOfIssuers is False.
InfiniteNumberOfIssuers	Specifies whether to model this portfolio with an infinite number of issuers of notes.
Frequency	The number of coupon payments per year for the notes in this portfolio. The options are (1, 2, 4, 12) so that it is aligned with ESG frequency options.
Seniority	The seniority of notes in this portfolio, which is used when utilizing default recovery rates.
Term	The initial term (maturity) of the notes. We validate the Term to ensure that the input Term is an integer multiple of $\frac{1}{\text{Frequency}}$.
InitialIndexValue	The initial value for index outputs.

Outputs

Name	Description
TotalReturn	The total return earned on an asset over the time interval. This is the sum of capital change and income return over this time period. $\text{TotalReturn}(t) = \text{CapitalChange}(t) + \text{IncomeReturn}(t)$ The output at time zero is meaningless and a value of 0 is given. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $\text{TotalReturn}(t') = \frac{\text{TotalReturnIndex}(t')}{\text{TotalReturnIndex}(t' - \Delta t')} - 1$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
AnnualisedTotalReturn	The annualized total return of this portfolio since the last output. $\text{AnnualisedTotaReturn}(t) = \text{AnnualisedCapitalChange}(t) + \text{AnnualisedIncomeReturn}(t)$
TotalReturnIndex	The total return index of an asset. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue

Name	Description
ExcessReturn	The excess return of this portfolio since the last output. $$\text{ExcessReturn}(t) = \frac{\text{ExcessReturnIndex}(t)}{\text{ExcessReturnIndex}(t - \Delta t)} - 1$$ The ExcessReturn at time zero is meaningless and a default value of 0 is given.
ExcessReturnIndex	The excess return index of this portfolio. $$\text{ExcessReturnIndex}(t) = \frac{\text{TotalReturnIndex}(t)}{\text{CashTotalReturnIndex}(t)}$$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in the value of the generic FRN portfolio that has occurred over this time step. This is calculated using the portfolio value at the start of the time step, $\text{PortfolioValue}(t - \Delta t)$, and the portfolio value at the end of the time step before rebalancing, $\text{PortfolioValuePreRebalancing}(t)$. That is: $$\text{CapitalChange}(t) = \frac{\text{PortfolioValuePreRebalancing}(t)}{\text{PortfolioValue}(t - \Delta t)} - 1$$ $\text{PortfolioValue}(t)$ and $\text{PortfolioValuePreRebalancing}(t)$ are defined in more detail below. The capital change at time zero is meaningless and a value of 0 is given. **Note** If the file output is not every time step, then it is calculated from the capital index as: $$\text{CapitalChange}(t') = \frac{\text{CapitalIndex}(t')}{\text{CapitalIndex}(t' - \Delta t')} - 1$$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
AnnualisedCapitalChange	The annualized capital change of this portfolio since the last output. $$\text{AnnualisedCapitalChange}(t) = (1 + \text{CapitalChange}(t))^{\frac{1}{\Delta t}} - 1$$ where Δt is the time between outputs.
CapitalIndex	The capital index of the generic FRN portfolio. This output is an index of capital changes, that is, the return excluding income. $$\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$$ where CapitalIndex(0) = InitialIndexValue
IncomeReturn	The income return of the generic FRN portfolio over this time period. This output is non-zero if and only if a coupon payment is received in this time period. The output is calculated as: $$\text{IncomeReturn}(t) = \frac{\text{CouponIncome}(t)}{\text{PortfolioValue}(t' - \Delta t')}$$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output and CouponIncome represents the coupons received over the time step. Each coupon is rolled up to the output time step at the credit risky rate of return; defaults are simulated at the end of each time step. Coupons from defaulted notes are reduced in a manner that reflects the recovery rate corresponding to the seniority of the note.
AnnualisedIncomeReturn	The annualized income return of this portfolio since the last output. $$\text{AnnualisedIncomeReturn}(t) = (1 + \text{IncomeReturn}(t))^{\frac{1}{\Delta t}} - 1$$ where Δt is the time between outputs.
IncomeYield	The income yield of the generic FRN portfolio. This output is calculated treating the Coupon input as if it were spread evenly over each reset period: $$\text{IncomeYield}(t) = \frac{\text{Coupon} \times \Delta t}{\text{PortfolioValue}(t - \Delta t)}$$

Name	Description
RedemptionYield	The gross redemption yield of this portfolio. It is essentially finding the value of RedemptionYield that satisfies the following equation: $$\text{PortfolioValue}(t) = \Sigma_{i=1}^{n} \frac{\left(\frac{\text{ZCBP}_c(\text{CreditClass},t_{i-1},\text{Seniority},t)}{\text{ZCBP}_c(\text{CreditClass},t_i,\text{Seniority},t)} - 1 + \frac{\text{Margin}(t)}{f} \right) \times \text{ZCBP}_p(\text{CreditClass}, t_i, \text{Seniority}, t)}{(1 + \text{RedemptionYield}(t))^{t_i}}$$ where the summation is over all the forecast payments, and payment times are as defined in the PortfolioValue output below.
PortfolioValue	The value of a single note (per unit nominal) in this portfolio at the start of the time step. $$\text{PortfolioValue}(t) = \text{ZCBP}_p(\text{CreditClass}, T, \text{Seniority}, t)$$ $$+ \sum_{i=1}^{n} \left(\frac{\text{ZCBP}_c(\text{CreditClass},t_{i-1},\text{Seniority},t)}{\text{ZCBP}_c(\text{CreditClass},t_i,\text{Seniority},t)} - 1 + \frac{\text{Margin}(t)}{f} \right) \times \text{ZCBP}_p(\text{CreditClass}, t_i, \text{Seniority}, t)$$ where: • ZCBP_p is the pricing curve. • ZCBP_c is the coupon curve. • T is the term. • f is the coupon frequency. • n is the number of forecast payments, which is $n = f \times T$. • The payment dates t_i are $t_i = \frac{i}{f}, i = 1, 2, \ldots n$. For the MarginAtPar strategy, the PortfolioValue is always 1.
PortfolioValuePreRebalancing	The portfolio value at the end of the time step immediately before rebalancing. When the simulation time step Δt is equal to or larger than the reset period 1/Frequency, it is: $$\text{PortfolioValuePreRebalancing}(t) = \text{ZCBP}_p(\text{CreditClass}, T - \Delta t, \text{Seniority}, t)$$ $$+ \sum_{i=1}^{m} \left(\frac{\text{ZCBP}_c(\text{CreditClass},s_{i-1},\text{Seniority},t)}{\text{ZCBP}_c(\text{CreditClass},s_i,\text{Seniority},t)} - 1 + \frac{\text{Margin}(t-\Delta t)}{f} \right) \times \text{ZCBP}_p(\text{CreditClass}, s_i, \text{Seniority}, t)$$ where ZCBP_p, ZCBP_c, and T are as defined in the PortfolioValue output above and: • The remaining payment dates s_i are $s_i = t_1 - \Delta t, t_2 - \Delta t, \ldots t_n - \Delta t$, with any entries less than or equal to zero removed (as these correspond to payments already made). • m is the number of forecast payments that are remaining. When the simulation time step Δt is smaller than the reset period 1/Frequency, the magnitude of the first payment still outstanding was set at the previous time step and hence is dependent on the yield curves at that time.
TransitionFreeReturn	The component of return that cannot be attributed to credit transitions (or defaults). It is the capital change that would have been earned if the portfolio had not experienced any change in credit rating or defaults. $$\text{TransitionFreeReturn}(t) = \frac{\text{PortfolioValue}(\text{InitialCreditRating}(t), t, \text{Term} - \Delta t)}{\text{PortfolioValue}(\text{InitialCreditRating}(t), t - \Delta t, \text{Term})} + \text{IncomeReturn}(t) - 1$$
CreditCost	The component of return attributable to credit transitions (including defaults). It is the difference between the actual capital change earned on the portfolio, and the capital change that would have been earned if the portfolio had not experienced any change in credit rating or defaults. This output is calculated as $\text{CreditCost} = \text{TotalReturn} - \text{TransitionFreeReturn}$.
Nominal	The nominal value of each note held.
NumUpgrades	The number of credit class upgrades since the last output.
NumDowngrades	The number of credit class downgrades since the last output.
NumDefaults	The number of defaults since the last output.

Name	Description
NumberOfNotes [CreditClass]	The number of notes of the specified credit class at the end of the time step immediately before rebalancing.
PortfolioProportion [CreditClass]	The proportion of the portfolio of the specified credit class at the end of the time step immediately before rebalancing. Calculated using the equation: $$\text{PortfolioProportion}(\text{CreditClass}, t) = \frac{\text{NumberOfNotes}(\text{CreditClass}, t)}{\text{NumberOfNotes}}$$
ReferenceRate	The reset rate of the notes. In reality, the reference rate on an FRN can be defined to be almost any interest rate. $$\text{ReferenceRate}(t) = \text{Frequency} \times \left(\frac{1}{\text{ZCBP}_c(\text{Govt}, 1/\text{Frequency}, t)} - 1 \right)$$ where the scaling by Frequency is to convert to an annualized quantity.
Margin	The margin above the coupon curve at which the purchased notes have been priced.
Term	The term of the notes in this portfolio after rebalancing has taken place.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the portfolio total return index discounted by the cash total return index of the base economy for all trials and takes the average.
Local Currency Asset Martingale Test	Calculates the portfolio total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average.

4.2.3 GenericIssuers

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The generic issuer container can hold issuers of fixed income assets. These assets can only be built on generic pools of issuers.

Addable submodels

Name	Description
GenericIssuerPool	A generic pool of organizations issuing fixed income assets.

GenericIssuerPool

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Generic issuer pools and their generic bond assets have similar behavior and modeling capabilities as generic bond portfolios. The main difference is that the GenericIssuerPool and GenericBondAsset solution can be used to model a true "Buy and Hold" strategy in which there is no rebalancing of credit class, except after a default, when the credit class is rebalanced to the initial credit class.

Addable submodels

Name	Description
GenericBondAsset	A bond that can be considered to have been issued by an "average" issuer.

Input variables

Name	Description
Strategy	This input describes how credit class transitions are dealt with. The following two options are available: • **Buy and hold**—Credit class is not rebalanced after each time step, except after a default, when the credit class is rebalanced to the initial credit class. • **Rebalance to original credit class**—Credit class is reset at the beginning of each time step.
Economy	The economy that the software uses for this bond issuer. The software only uses this input to achieve independence between credit rating transitions and the primary nominal yield curve of the economy.
CreditModel	The model that the software uses to determine credit rating transition probabilities within the generic issuer pool. **Note** If you set **InitCreditClass** to **Govt** , the software does not use this input. However, you must still select a value.
EquityAsset	The equity asset that the software uses to calculate the credit migration factor, which drives the common undiversifiable component of credit rating transitions in the bond portfolio. If CreditMigrationFactorMethod is set to EquityZScore or StandardisedExcessLogReturn, then the correlation between the credit migration factor and the pricing yield curve is removed.
InitCreditClass	The initial credit class of the issuer pool. Select **Govt** for a risk free pool, or credit class from **AAA** through to **CCC** for credit risky issuers.
TotalNumIssuers	The total number of issuers in the pool. Having more issuers means that the credit transitions are less granular and more generic in nature, but this option comes at the cost of a longer run time. For a risk free pool (that is, Govt), there is no advantage in having any more than one issuer.

Outputs

Name	Description
NumIssuers [CreditClass]	The number of issuers in the specified credit class at the end of the time step.
PoolProportion [CreditClass]	The proportion of issuers in the specified credit class at the end of the time step, calculated as: $\text{PoolProportion}(CreditClass, t) = \frac{\text{NumIssuers}(CreditClass, t)}{\text{TotalNumIssuers}}$

Name	Description
NumUpgrades	The number of upgrades over the time step.
NumDowngrades	The number of downgrades over the time step.
NumDefaults	The number of defaults over the time step.

GenericBondAsset

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Generic bond assets have similar behavior and modeling capabilities as GovtGenericBondPortfolios and RiskyGenericBondPortfolios. The main exception is that, because of the way they are linked to a GenericIssuerPool, they can be used to model a true Buy and Hold strategy in which there is no rebalancing of credit class. This is not possible in RiskyGenericBondPortfolios.

The software uses the **CreditModel** and credit class of the parent **GenericIssuerPool** for credit class rebalancing and pricing of credit-risky bonds

Note The software prices credit-risky bonds analytically under the assumption that credit rating transitions are independent of the cash total return index of the pricing yield curve. Martingale tests therefore only pass if you set up the **CorrelationMatrix** accordingly.

Input variables

Name	Description	Conditions
Strategy	The strategy defines how bonds are rebalanced over time. The following two options are available: • **Fixed coupon and maturity**—The term and coupons of the bond are reset at the beginning of each time step. • **Buy and hold**—The bonds are held until maturity without rebalancing the term.	
Economy	The denomination of the issued bond.	
InflationRates	The inflation model that you want to use to price bond assets and calculate inflation-linked increases. Bonds are priced using the real yield curve selected in the inflation model. The coupon and principal payments are inflated using the inflation index of the inflation model that you select.	Enabled only after you select an economy, and if **BondType** is **Index Linked**.
BondType	The bonds can be nominal bonds or index-linked bonds. Nominal bonds are priced using the nominal yield curve, and index-linked bonds are priced using the real yield curve selected in the inflation model. Inflation is also considered when deriving the returns of index-linked bonds.	
Coupon	The annual coupon rate of the bonds.	
CouponFreq	The number of coupon payments per year.	

Name	Description	Conditions
Seniority	Seniority of the bonds in the portfolio. This input is linked to a table of expected recovery rates associated with the economy of the bonds.	
Term	The term to maturity of the bonds.	
DefaultStrategy	Specifies how recoveries from defaulted bonds are dealt with. The following two options are available: • **Treat as a net cashflow**—Recoveries are treated as a cash flow. • **Reinvest into bond portfolio**—Recoveries are used to purchase bonds according to the bond portfolios current credit class distribution.	

Outputs

Name	Description
TotalReturn	The total return earned on an asset over the time interval. This output is the sum of capital change and income return over this time period. $$\text{TotalReturn}(t) = \text{CapitalChange}(t) + \text{IncomeReturn}(t)$$ The output at time zero is meaningless and a value of 0 is given. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $$\text{TotalReturn}(t') = \frac{\text{TotalReturnIndex}(t')}{\text{TotalReturnIndex}(t' - \Delta t')} - 1$$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
TotalReturnIndex	The total return index of an asset. $$\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$$ where TotalReturnIndex(0) = 1.
RescaledTRI [StartVal]	The total return index (TRI) of this asset, rescaled by a designated value. This feature has been superseded by the InitialIndexValue parameter.
ExcessReturn	The return earned on the asset in excess of the risk free return.
ExcessReturnIndex	The excess return index of the asset. $$\text{ExcessReturnIndex}(t) = \text{ExcessReturnIndex}(t - \Delta t) \times (1 + \text{ExcessReturn}(t))$$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in the value of the bond asset that has occurred over this time step. This output is calculated using the portfolio value at the start of the time step, and the portfolio value at the end of the time step before rebalancing. The capital change at time zero is meaningless and a value of 0 is given. **Note** If the file output is not every time step, then it is calculated from the capital index as: $$\text{CapitalChange}(t') = \frac{\text{CapitalIndex}(t')}{\text{CapitalIndex}(t' - \Delta t')} - 1$$ where t' are the time steps that are actually output.

Name	Description
CapitalIndex	The capital index of the generic bond portfolio. This output is an index of bond capital changes, that is, the total return excluding income. $\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$ where CapitalIndex(0) = 1.0.
IncomeReturn	The income return of the generic bond portfolio over this time period. This output is non-zero if and only if a coupon payment is received in this time period. The output is calculated as: $\text{IncomeReturn}(t) = \frac{\text{Income}(t)}{\text{Price}(t - \Delta t)}$
RedemptionYield	The gross redemption yield (also known as internal rate of return or yield to maturity) of the asset. It is the constant (discretely compounded) discount rate that would make the sum of discounted future cash flows equal to the present PortfolioPricePostRebalancing. If the portfolio contains nominal bonds, then the yield is reported as a nominal yield. If the portfolio contains index-linked bonds, then the yield is reported as a real yield.
Price	This output is slightly different from other Price outputs in the software. It is actually a capital index scaled by the initial price of the portfolio, calculated as $\text{Price}(t) = \text{Price}(t - \Delta t) \times \frac{\text{PortfolioPricePreRebalancing}(t)}{\text{PortfolioPricePostRebalancing}(t - \Delta t)}$ with Price(0) = PortfolioPricePostRebalancing(0).
Holding	The quantity of this asset held over the time step. This output has an initial value of 1.0, and might be adjusted during rebalancing to reflect that we might be able to buy more than (or less than) one unit of the rebalancing asset with the proceeds of the sale of the previous asset.
PortfolioPricePreRebalance	The value of a single unit of the portfolio immediately before rebalancing (that is, one nominal unit) at this time step. This output is defined as being the sum of discounted expected future cash flows, adjusted for default and any subsequent recovery.
PortfolioPricePostRebalance	The value of a single unit of the portfolio immediately after rebalancing (that is, one nominal unit) at this time step. This output is defined as being the sum of discounted expected future cash flows, adjusted for default and any subsequent recovery.
Income	The net cash flow from the asset over the time step per unit of the asset, including coupons and principal. If the individual cash flows are received part way through the time step, they are rolled up to the end of the time step.
DefaultIncome	Recoveries received from defaulted bonds. **Note** This output depends on the **DefaultStrategy** selected.
Duration	Weighted average duration of the bonds in the portfolio. Individual bond duration is determined by the following equation: $V_s = \frac{\sum_t tC_t v^t}{\sum_t C_t v^t}$ where $v = \frac{1}{(1+it)}$ and *i* is yield of the appropriate credit class and term.
ExpectedCashflows [Term]	A simple sum of cash flows that are expected to be paid in the year leading up to at a particular time (term) into the future (relative to the current time step).

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index for all trials and takes the average.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

4.2.4 SpecificIssuers

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This container can hold issuers of fixed income assets of various types.

Addable submodels

Name	Description	Availability
BondIssuer	An organization issuing bonds or floating rate notes (FRNs).	
MunicipalIssuer	An organization issuing municipal bonds.	
MBSIssuer	An MBS issuing agency. This model is aimed at US agency MBS. For the DanishMBS model, use the CallableSecurityIssuer.	
CallableSecurityIssuer	An issuer of various securities with embedded American or Bermudan call options. This includes a specific model for Danish MBS, and a more generic model suitable for other MBS, callable bonds, ABS, and so on.	
G2CreditStatisticalSpreadIssuer	An organization issuing bonds. The underlying transition and spread model is the G2CreditStatisticalSpread model.	RSG

BondIssuer

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An organization issuing bonds or floating rate notes (FRNs).

Addable submodels

Name	Description
Bond	A specific bond issued by this bond issuer.
FRN	A floating rate note issued by this bond issuer.

Input variables

Name	Description
CreditClass	The initial credit class of this issuer.
CreditModel	The model that the software uses to determine credit rating transition probabilities of the specific issuer. **Note** If you set **CreditClass** to **Govt**, the software does not use this input. However, you must still select a value.
EquityAsset	The equity asset that the software uses to calculate the credit migration factor, which drives the common undiversifiable component of credit rating transitions in the bond portfolio. If CreditMigrationFactorMethod is set to EquityZScore or StandardisedExcessLogReturn, then the correlation between the credit migration factor and the pricing yield curve is removed.

Outputs

Name	Description
CreditClassIndex	The credit class of the issuer as number: • 0 = Govt • 1 = AAA • 2 = AA • 3 = A • 4 = BBB • 5 = BB • 6 = B • 7 = CCC • 8 = Default
CreditClass	The credit class of the issuer in text form (AAA, AA, and so on).
SpotSpread [Maturity, Seniority]	The spot spread for the specified maturity and seniority.
FundamentalSpread [Maturity, Seniority]	The fundamental spread for the specified maturity and seniority. This output is the part of the spread which is required to compensate for losses due to defaults, taking into account the possibility of rating transitions (and assuming that the associated equity ZScoreMPR is zero). This output is only supported for real world simulations if the credit stochastic driver is using a zero market price of risk.

Bond

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Note The software prices credit-risky bonds analytically under the assumption that credit rating transitions are independent of the cash total return index of the pricing yield curve. Martingale tests therefore only pass if you set up the **CorrelationMatrix** accordingly

Input variables

Name	Description	Conditions
Economy	The denomination of the issued bond.	
InflationRates	The inflation model that you want to use to price the bond and calculate inflation-linked increases. The bond is priced using the real yield curve selected in the inflation model. The coupon and principal payments are inflated using the inflation index of the inflation model that you select.	Enabled only after you select an economy, and if **BondType** is **Index Linked**.
Coupon	The annual coupon rate of this bond.	
MaturityDate	The date on which the bond matures.	
CouponFrequency	The coupon frequency of the bond.	
Seniority	The seniority of the bond.	
CashFlowSchedule	The cash flow for non-vanilla bonds.	
BondType	**Nominal** or **Index Linked**. Nominal bonds are priced using the nominal yield curve, and index-linked bonds are priced using the real yield curve selected in the inflation model. Inflation is also considered when deriving the returns of index-linked bonds.	
RecoveryConvention	There are two conventions for the timing of the payment of recovery value on default: • **Cash Settlement**—On default the discounted present value of the recovery value is received immediately as cash. • **Treasury Bond**—After default coupon and principal payments are reduced by the recovery rate and paid at the dates originally specified. These payments are guaranteed.	

Outputs

Name	Description
Price	The price of the bond.
TotalReturn	The total return earned on the asset over the time step. The output at time zero is meaningless and a default value of 0 is given.
TotalReturnIndex	The total return index of an asset. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t-\Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = 1.
ExcessReturn	The return earned on the asset in excess of the risk free return.

Name	Description
ExcessReturnIndex	The excess return index of the asset. $\text{ExcessReturnIndex}(t) = \text{ExcessReturnIndex}(t - \Delta t) \times (1 + \text{ExcessReturn}(t))$ where ExcessReturnIndex(0) = 1.
CapitalReturn	The capital change of the asset over the time step.
CapitalIndex	The capital index of the asset.
IncomeYield	The amount of income arising within this asset, as a proportion of the previous (time step) price.
IncomeReturn	The return on income.
Payments	The payments of the bond.
Principal	The principal payment of the bond.

FRN

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A floating rate note.

Input variables

Name	Description
Economy	The denomination of the issued note.
Margin	The margin above the coupon curve used to determine the coupon.
Maturity	The term to maturity of the note in years.
CouponFrequency	The number of coupon payments per year.
TimeSinceLastReset	The time in years since the last reset. Must be less than 1/CouponFrequency. Maturity+TimeSinceLastReset must be divisible by 1/CouponFrequency.
LastResetRate	The rate that the next interest payment will be based on.
Seniority	The seniority of the note.

Outputs

Name	Description
Price	The price of the note.
Payments	The payments of the note.
Principal	The principal payment of the note.

Name	Description
IncomeReturn	The income return from the note.
CapitalChange	The capital value change of the note.
TotalReturn	The total return of the note.

MunicipalIssuer

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An organization issuing municipal bonds.

Addable submodels

Name	Description
MunicipalBond	A municipal bond issued by a municipal issuer.

Input variables

Name	Description
MunicipalSpread	The municipal spread that the software uses for bond pricing. The **Economy** of the **MunicipalSpread** determines the denomination of the issued bond.
EquityAsset	The equity asset that the software uses to calculate the credit migration factor, which drives the common undiversifiable component of credit rating transitions in the bond portfolio. If CreditMigrationFactorMethod is set to EquityZScore or StandardisedExcessLogReturn then the correlation between the credit migration factor and the pricing yield curve is removed.
CreditClass	The initial credit class of this issuer.

Outputs

Name	Description
CreditClassIndex	The credit class of the issuer as number: • 0 = Govt (Gilts) • 1 = AAA • 2 = AA • 3 = A • 4 = BBB • 5 = BB • 6 = B • 7 = CCC

Name	Description
	• 8 = Default
CreditClass	The credit class of the issuer in text form (AAA, AA, and so on).

MunicipalBond

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A municipal bond issued by a municipal issuer.

Input variables

Name	Description
Coupon	The annual coupon rate of this bond.
Maturity Date	The date on which the bond matures.
CouponFrequency	The coupon frequency of the bond.
Seniority	The seniority of the bond.
CashFlowSchedule	The cash flow for non-vanilla bonds.
BondType	The type of a bond in a portfolio.

Outputs

Name	Description
Price	The price of the bond.
TotalReturn	The total return earned on the asset over the time step. The output at time zero is meaningless and a default value of 0 is given.
TotalReturnIndex	The total return index of the asset. $\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t - \Delta t) \times (1 + \mathrm{TotalReturn}(t))$ where TotalReturnIndex(0) = 1.
ExcessReturn	The return earned on the asset in excess of the risk free return.
ExcessReturnIndex	The excess return index of the asset. The software calculates this output using the following equation. $\mathrm{ExcessReturnIndex}(t) = \mathrm{ExcessReturnIndex}(t - \Delta t) \times (1 + \mathrm{ExcessReturn}(t))$ where ExcessReturnIndex(0) = 1.
CapitalReturn	The capital change of the asset over the time step.
CapitalIndex	The capital index of the asset.

Name	Description
IncomeYield	The amount of income arising within this cash asset, as a proportion of the previous (time step) price.
IncomeReturn	The return on income.
Payments	The payments of the bond.

MBSIssuer

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An MBS issuing agency and the associated MBS that are issued. The input parameters described here apply to each of the MBS that is defined for this MBS issuer. This model is aimed at US agency MBS.

Addable submodels

Name	Description
MBS	Describes a particular MBS issued by this agency.

Input variables

Name	Description
Economy	The economy in which the market is denominated. This economy must be using the TwoFactorBKExt nominal yield curve model.
PSAspeed	The rate of the deterministic part of unscheduled prepayment, expressed as a proportion of the Public Securities Association (PSA) (now the Securities Industry and Financial Markets Association) prepayment schedule. *For example*, an input of 0.9 represents 90% of the PSA benchmark. The maximum input value is 16.66, because this results in the entire pool of loans refinancing.
OASmbs	The option adjusted spread (OAS) for this MBS issuer, representing the credit risk of this agency.
RefinancingCost	The cost of refinancing a mortgage as a proportion of the outstanding balance at the time refinancing is considered.
LaggardDistribution	The laggard distribution describes the behavior of mortgage holders in this market. The distribution is represented by 10 discrete laggard categories, each with a spread and the proportion of mortgage holders in the underlying pool that belong to this category at the start of the simulation. For more information, see the Mortgage-Backed Securities methodology.

MBS

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model is aimed at US agency MBS and uses a laggard distribution to model suboptimal refinancing. For information about the possibilities for MBS and callable security modeling, see the Mortgage-Backed Securities methodology.

Each MBS requires information about the underlying mortgages and the MBS itself.

Input variables

Name	Description
Strategy	The strategy of rebalancing or reinvestment. Possible values: • **Buy and Hold**—The MBS is held to maturity and cash flows are reinvested into the same security. • **Prevailing Rate**—The MBS is rebalanced into an MBS that has MBSCoupon and MtgeCoupon derived from the prevailing yield curve at the time of rebalancing, and all other parameters reset to their initial values. RebalancingFrequency defines the frequency of rebalancing.
RebalancingFrequency	Defines the time steps at which rebalancing occurs when the Prevailing Rate strategy is being used. Can either be Each time step or Annually.
MtgeTerm	The full term of the mortgages underlying the MBS.
MtgeCoupon	The weighted average coupon (WAC) for the mortgages underlying the MBS. This input is equivalent to a weighted average of the fixed rates that the mortgage holders are paying. If the Prevailing Rate strategy is being used, the MtgeCoupon is derived from the MtgeCouponSpread input.
MtgeCouponFreq	The frequency of payments on the underlying mortgages. This parameter is fixed at 12, indicating monthly mortgage payments.
Age	The weighted average age (in months) of the mortgages underlying the MBS at the start of the simulation.
SurvivalFactor	The remaining weighted average proportion of the mortgage pool that has not refinanced or prepaid in an unscheduled manner. See the following section on survival factor for more details.
MBSCoupon	The coupon payable on an investment in this MBS, if the Prevailing Rate strategy is being used the MBSCoupon is derived from the MBSCouponSpread input.
OASMtge	The option adjusted spread of the mortgage pool.
PrevailingSpotRateTerm	When the Prevailing Rate strategy is used, this input defines the term of the prevailing spot rate that is used to derive the MBSCoupon and MtgeCoupon.
MBSCouponSpread	When the Prevailing Rate strategy is used, this input defines the MBS coupon as a spread above the prevailing annually compounded spot rate of term equal to PrevailingSpotRateTerm. $\text{MBSCoupon} = \text{PrevailingSpotRate} + \text{MBSCouponSpread}$
MtgeCouponSpread	When the Prevailing Rate strategy is used, this input defines the mortgage coupon as a spread above the prevailing annually compounded spot rate of term equal to PrevailingSpotRateTerm. $\text{MtgeCoupon} = \text{PrevailingSpotRate} + \text{MtgeCouponSpread}$

Outputs

Name	Description
Value	The value of the MBS. This output is the option-adjusted sum of discounted expected future cash flows and is after any refinancing and/or rebalancing have been taken into account.

Name	Description
Price	The price of the asset on a "per unit outstanding balance" basis, defined as $$\text{Price}(t) = \frac{\text{Value}(t)}{\text{Balance}(t)}$$
TotalReturn	The total return earned over the time interval. This output is the net result of any changes in value of the MBS and the value of reinvestment of cash flows. $$\text{TotalReturn}(t) = \frac{(\text{ValuePreRebalancing}(t) + \text{TotalCashflow}(t))}{\text{Value}(t - \Delta t)} - 1$$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $$\text{TotalReturn}(t') = \frac{\text{TotalReturnIndex}(t')}{\text{TotalReturnIndex}(t' - \Delta t')} - 1$$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
TotalReturnIndex	The total return index of the MBS. $$\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$$ where TotalReturnIndex (0) = 1.
ExcessReturn	The return earned on the asset in excess of the risk free return.
ExcessReturnIndex	The excess return index of the asset. The software calculates this output using the following equation. $$\text{ExcessReturnIndex}(t) = \text{ExcessReturnIndex}(t - \Delta t) \times (1 + \text{ExcessReturn}(t))$$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in capital value over the time step, calculated as: $$\text{CapitalChange}(t) = \frac{\text{ValuePreRebalancing}(t)}{\text{Value}(t - \Delta t)} - 1$$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place. If the file output is not every time step, then it is recalculated from an index so as to represent the capital change since the previous time step that is actually output.
IncomeReturn	The component of return due to income, where all the cash flows are treated as income. $$\text{IncomeReturn}(t) = \frac{\text{TotalCashflow}(t)}{\text{Value}(t - \Delta t)}$$
TotalCashflow	The net cash flow received over the course of this time step. This output has four components: $$\text{TotalCashFlow}(t) = \text{Interest}(t) + \text{Principal}(t) + \text{Prepayment}(t) + \text{Refinancing}(t)$$
Interest	The component of the total cash flow received over this time step that is due to interest payments.
Principal	The component of the total cash flow received over this time step that is due to scheduled principal repayments.
Prepayment	The component of the total cash flow received over this time step that is due to any curtailment, unscheduled prepayment, or complete mortgage refinancing that is not correlated to interest rate movements.

Name	Description
RefinancingCashflow	The component of the total cash flow received over this time step due to complete mortgage refinancing that is correlated to interest rate movements.
Balance	The proportion of the initial mortgage balance that is outstanding at the end of this time period.
Nominal	The number of units of this asset that are held. This output can change on rebalancing which mimics the action of selling the holding and buying a new asset with the proceeds. Depending on the value of the new asset, we might be able to buy more than (or less than) one unit of the new asset. The software calculates this output using the following equation. $$\text{Nominal}(t) = \text{Nominal}(t - \Delta t) \times \frac{\text{ValuePreRebalancing}}{\text{Value}(t)}$$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place.
MBSCoupon	The coupon value that is actually being applied for the next time step. This output can vary over time when the Prevailing Rate rebalancing strategy is used.
MrtgCoupon	The mortgage coupon value that is actually being applied for the next time step. This output can vary over time when the Prevailing Rate rebalancing strategy is used.
Refinanced [Index]	True/False indication of whether it would be appropriate for laggard type <Index> to refinance in this time step according to the prevailing yield curve.
LaggardProportion [Index]	The proportion of the total initial pool of mortgages in laggard type <Index> that has not refinanced up to and including this time step.

Survival Factor Versus Pool Factor

Note the widely accepted definition of pool factor, which is the proportion of the original balance that is outstanding. Since the loan is amortizing the outstanding balance naturally reduces over time, even when there are no unscheduled payments. The survival factor takes account of unscheduled payments only, meaning that if there are no unscheduled payments over a given period the survival factor remains constant.

To convert from a pool factor to a survival factor that is suitable for input here, divide the pool factor by the scheduled remaining balance for mortgages at the input value of Age. This scheduled remaining balance (assuming no unscheduled payments at all) is given by the following equation.

$$\text{ScheduledRemainingBalance} = \frac{1 - (1+b)^{-\text{RemainingTerm}\times\text{MtgeCouponFreq}}}{1 - (1+b)^{-\text{MtgeTerm}\times\text{MtgeCouponFreq}}}$$

where

$$b = \frac{\text{Mtgecoupon}}{\text{MtgeCouponFreq}}$$

and the remaining term in years is defined in terms of the Age by:

$$\text{RemainingTerm} = \text{MtgeTerm} - \frac{Age}{12}$$

CallableSecurityIssuer

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

An issuer of various securities with embedded American/Bermudan call options.

Addable submodels

Name	Description
CallableSecurity	A generic callable security, suitable for modeling callable bonds, MBS, CMBS, ABS, and other securities with embedded call options.
DanishMBS	A Danish-style MBS in which the underlying mortgages have a refinance (at a cost) option and also a buyback option.

Input variables

Name	Description
Economy	The economy in which this issuer and all of its underlying securities are denominated. All securities are priced from the primary nominal yield curve of this economy.
OASIssuer	An option adjusted spread of the issuer in basis points. This output is modeled as a constant spread over the risk free rate.

CallableSecurity

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The CallableSecurity model is a generic model that can be used to model several different types of securities with American/Bermudan call options. This includes some types of MBS, asset backed securities (ABS), commercial mortgage backed securities (CMBS), and others.

All securities are based on (backed by) fixed rate loans, with the loan having a refinance option. There are other features enabling the possibility of interest only periods, lockout periods, a buyback (delivery) option, and so on. For information about the possibilities for MBS and callable security modeling, see the Mortgage-Backed Securities methodology.

Submodels

Name	Description
FRN	A riskless floating rate note used for reinvestment of cash flows when the FRN Reinvestment Buy And Hold strategy is being used.

Input variables

Name	Description
Strategy	The strategy of rebalancing and/or reinvestment. Possible values: • **Buy And Hold**—The security is held to maturity and cash flows are reinvested into the same security. • **FRN Reinvestment Buy And Hold**—The security is held to maturity and cash flows are reinvested into the uncallable floating rate note (FRN) submodel. • **Prevailing Rate**—The security is rebalanced into a security that has LoanCoupon and Coupon derived from the prevailing yield curve at the time of rebalancing, and all other parameters reset to their initial values. The frequency of rebalancing is defined by the RebalancingFrequency input.
RebalancingFrequency	Defines the time steps at which rebalancing occurs when the Prevailing Rate strategy is being used. Can either be Each time step or Annually.
BuyBackOption	Indicates whether the buyback (delivery) option is to be modeled.
Strike	The strike of the call option expressed as a proportion of the outstanding balance. *For example*, enter 1.0 for an option struck at par, or 1.05 for a callable bond struck at 105.
Term	The total term in years of the mortgages in the underlying pool when they were first issued.
InterestOnlyPeriod	The initial period over which the underlying mortgages are interest only (meaning that there is no repayment of principal). Over the remainder of their term the mortgages are annuity style (interest and principal) loans.
LoanCoupon	The fixed coupon rate of the underlying mortgage loans. This is expressed as a proportion, so, *for example*, enter 0.05 for 5%. If the Prevailing Rate strategy is being used, the LoanCoupon is derived from the LoanCouponSpread input.
LoanCouponFreq	The frequency of payments that the mortgage holders are required to make on their loans. Enter the number per annum.
Age	The weighted average age (in months) of the underlying mortgages at the start of the simulation.
SurvivalFactor	The remaining weighted average proportion of the mortgage pool that has not refinanced and/or prepaid in an unscheduled manner. See the following section about survival factor for more details.
Coupon	The coupon payable on an investment in this security. Enter this parameter as a proportion, *for example*, enter 0.05 for 5%. If the Prevailing Rate strategy is being used, the Coupon is derived from the CouponSpread input.
OASLoans	The option adjusted spread of the underlying loans in basis points. This parameter has an impact on refinancing rates.
PSASpeed	The rate of the deterministic part of unscheduled prepayment, expressed as a proportion of the US Public Securities Association (PSA) (now the Securities Industry and Financial Markets Association) prepayment schedule. *For example*, an input of 0.9 represents 90% of the PSA benchmark. The maximum input value is 16.66, because this value results in the entire pool of loans refinancing.
LockOutPeriod	An initial period of the loans over which there can be no refinancing or prepayments. Enter the period in years.
RequiredGainDistribution	This parameter defines the parameters of the individual groups of underlying loans in terms of the refinancing costs associated with refinancing and the distribution of gains they require before they consider refinancing. Each row in the RequiredGainDistribution represents a group, and groups can be added or deleted as required. The distribution of required gains for each group is modeled as a truncated normal distribution, with parameters are defined as follows: • **Description**—A string identifier for the group. This exact string description must be used in the AvailableGain, ProportionRefinancing, and RemainingProportion outputs.

Name	Description
	• **Weight**—The weightings of the groups making up the security at the start of the simulation. The weightings of all groups must sum to 1.0. • **RelativeMeanGain**—A component of the mean of the normal distribution that depends on the outstanding balance. • **AbsoluteMeanGain**—An absolute component of the mean of the normal distribution. • **ARMsInclination**—The component of the mean of the normal distribution contributing the inclination of loan holders to refinance into adjustable rate loans. • **StandardDeviation**—The standard deviation of the underlying normal distribution. If this is set to zero, then the cumulative distribution collapses to a step function. • **VariableRefinanceCost**—Refinancing costs that are proportional to the outstanding balance at the time of refinancing. Expressed as a proportion. • **FixedRefinanceCost**—Refinancing costs that are fixed, regardless of the outstanding balance of the underlying mortgages. Expressed as a proportion. • **HitRatio**—The hit ratio describes the maximum proportion of the loan pool that can refinancing over a period of one year, if favorable refinancing conditions exist for the full year. If finer time steps are used, then the maximum proportion is adjusted consistently.
PrevailingSpotRateTerm	When the Prevailing Rate strategy is used, this input defines the term of the prevailing spot rate that is used to derive the Coupon and LoanCoupon.
CouponSpread	When the Prevailing Rate strategy is used, this input defines the coupon as a spread above the prevailing annually compounded spot rate of term equal to PrevailingSpotRateTerm. $\text{Coupon} = \text{PrevailingSpotRate} + \text{CouponSpread}$
LoanCouponSpread	When the Prevailing Rate strategy is used, this input defines the loan coupon as a spread above the prevailing annually compounded spot rate of term equal to PrevailingSpotRateTerm. $\text{LoanCoupon} = \text{PrevailingSpotRate} + \text{LoanCouponSpread}$
EnableNegativeCoupons	Specify whether coupons are allowed to take negative values.

Outputs

Name	Description
Value	The value of the security. This output is the option-adjusted sum of discounted expected future cash flows and is after any refinancing and/or rebalancing have been taken into account.
Price	The price of the asset on a "per unit outstanding balance" basis, defined as $\text{Price}(t) = \frac{\text{Value}(t)}{\text{Balance}(t)}$
TotalReturn	The total return earned over the time interval. This output is the net result of any changes in value of the MBS as well as the value of reinvestment of cash flows. $\text{TotalReturn}(t) = \frac{(\text{ValuePreRebalancing}(t) + \text{TotalCashflow}(t))}{\text{Value}(t - \Delta t)} - 1$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $\text{TotalReturn}(t') = \frac{\text{TotalReturnIndex}(t')}{\text{TotalReturnIndex}(t' - \Delta t')} - 1$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.

Name	Description
TotalReturnIndex	The total return index of the MBS. $$\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$$ where TotalReturnIndex (0) = 1.
ExcessReturn	The return earned on the asset in excess of the risk free return.
ExcessReturnIndex	The excess return index of the asset. The software calculates this output using the following equation. $$\begin{aligned}&\text{ExcessReturnIndex}(t)\\&\quad = \text{ExcessReturnIndex}(t - \Delta t) \times (1 + \text{ExcessReturn}(t))\end{aligned}$$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in capital value over the time step, calculated as: $$\text{CapitalChange}(t) = \frac{\text{ValuePreRebalancing}(t)}{\text{Value}(t - \Delta t)} - 1$$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place. If the file output is not every time step then it is recalculated from an index so as to represent the capital change since the previous time step that is actually output.
IncomeReturn	The component of return due to income, where all of the cash flows are treated as income. $$\text{IncomeReturn}(t) = \frac{\text{TotalCashflow}(t)}{\text{Value}(t - \Delta t)}$$
TotalCashflow	The net cash flow received over the course of this time step. This output has four components: $$\begin{aligned}\text{TotalCashFlow}(t) &= \text{Interest}(t) + \text{Principal}(t)\\&\quad + \text{Prepayment}(t) + \text{Refinancing}(t)\end{aligned}$$
Interest	The component of the total cash flow received over this time step that is due to interest payments.
Principal	The component of the total cash flow received over this time step that is due to scheduled principal repayments.
Prepayment	The component of the total cash flow received over this time step that is due to any curtailment, unscheduled prepayment, or complete loan refinancing that is not correlated to interest rate movements.
RefinancingCashflow	The component of the total cash flow received over this time step due to complete loan refinancing that is correlated to interest rate movements.
Balance	The proportion of the initial loan balance that is outstanding at the end of this time period.
Nominal	The number of units of this asset that are held. This output can change on rebalancing which mimics the action of selling the holding and buying a new asset with the proceeds. Depending on the value of the new asset, we might be able to buy more than (or less than) one unit of the new asset. The software calculates this output using the following equation. $$\text{Nominal}(t) = \text{Nominal}(t - \Delta t) \times \frac{\text{ValuePreRebalancing}}{\text{Value}(t)}$$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place.
Coupon	The coupon value that is actually being applied for the next time step. This output can vary over time when the Prevailing Rate rebalancing strategy is used.
LoanCoupon	The loan coupon value that is actually being applied for the next time step. This output can vary over time when the Prevailing Rate rebalancing strategy is used.

Name	Description
ReinvestmentValue	The total value of the reinvestment in the FRN submodel. This output is only used with the FRN Reinvestment Buy And Hold strategy.
AvailableGain [Description]	The gain available for refinancing for the group with label **Description**. **Description** must match exactly the description given for this group in the required gain distribution.
ProportionExercising [Description]	The proportion of the remaining mortgage holders in this group. **Description** must match exactly the description given for this group in the required gain distribution.
RemainingProportion [Description]	The proportion of the initial mortgage balance that remains in the group with label **Description**. **Description** must match exactly the description given for this group in the required gain distribution.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the base economy for all trials and takes the average.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average.

FRN

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A floating rate bond that can be used for reinvesting cash flows of its parent CallableSecurity only (and only if the callable security uses the FRN reinvestment strategy). This FRN is not subject to default. In addition, the FRN is rebalanced each time step into an FRN with the maturity as input. In this regard, it is different to the full feature FRN model available under bond issuers.

Input variables

Name	Description
Maturity	The term to maturity (in years) of the FRN.
Margin	The fixed margin over the risk free rate that is paid on this FRN. Enter this parameter as a proportion, *for example*, enter 0.01 for a 1% (100 bp) margin.
CouponFrequency	The frequency of coupon resets (and coupon payments) on the FRN. This parameter is expressed as a number per annum, and is constrained to be equal to the simulation time step so that exactly one coupon is received each time step.

Outputs

Name	Description
Price	The price of the FRN.

Name	Description
TotalReturn	The simply compounded total return earned over the time interval. This output is the net result of capital changes and coupons received.

Survival Factor versus Pool Factor

Note the widely accepted definition of pool factor, which is the proportion of the original balance that is outstanding. Since the loan is amortizing the outstanding balance naturally reduces over time, even when there are no unscheduled payments. The survival factor takes account of unscheduled payments only, meaning that if there are no unscheduled payments over a given period the survival factor remains constant.

To convert from a pool factor to a survival factor that is suitable for input here, divide the pool factor by the scheduled remaining balance for mortgages at the input value of Age. This scheduled remaining balance (assuming no unscheduled payments at all) is given by the following equation.

$$\mathrm{ScheduledRemainingBalance} = \frac{1-(1+b)^{-\mathrm{RemainingTerm}\times\mathrm{MtgeCouponFreq}}}{1-(1+b)^{-\mathrm{MtgeTerm}\times\mathrm{MtgeCouponFreq}}}$$

where

$$b = \frac{\mathrm{Mtgecoupon}}{\mathrm{MtgeCouponFreq}}$$

and the remaining term in years is defined in terms of the Age by:

$$\mathrm{RemainingTerm} = \mathrm{MtgeTerm} - \frac{Age}{12}$$

DanishMBS

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A Danish-style MBS backed by fixed rate callable mortgage loans. The underlying mortgages have a refinance (at a cost) option and also a buyback (delivery) option. For information about the possibilities for MBS and callable security modeling, see the Mortgage-Backed Securities methodology.

Submodels

Name	Description
FRN	A riskless floating rate note used for reinvestment of cash flows when the FRN Reinvestment Buy And Hold strategy is being used.

Input variables

Name	Description
Strategy	The strategy of rebalancing or reinvestment. Possible values: • **FRN Reinvestment Buy And Hold**—The MBS is held to maturity and cash flows are reinvested into the uncallable floating rate note (FRN) submodel. • **Buy and Hold**—The MBS is held to maturity and cash flows are reinvested into the same MBS. • **Prevailing Rate**—The security is rebalanced into a security that has Coupon and MortgageCoupon derived from the prevailing yield curve at the time of rebalancing, and all other parameters reset to their initial values. The frequency of rebalancing is defined by the RebalancingFrequency input.
RebalancingFrequency	Defines the time steps at which rebalancing occurs when the Prevailing Rate strategy is being used. Can either be Each time step or Annually.
Term	The total term in years of the mortgages in the underlying pool when they were first issued.
InterestOnlyPeriod	The initial period over which the underlying mortgages are interest only (meaning that there is no repayment of principal). Over the remainder of their term the mortgages are annuity style (interest and principal) loans.
MortgageCoupon	The fixed coupon rate of the underlying mortgage loans. Enter this parameter as a proportion, *for example*, enter 0.05 for 5%.
MortgageCouponFrequency	The frequency of payments that the mortgage holders are required to make on their loans. This parameter is expressed as a number per annum.
Age	The weighted average age (in months) of the underlying mortgages at the start of the simulation.
SurvivalFactor	The remaining weighted average proportion of the mortgage pool that has not refinanced and/or prepaid in an unscheduled manner. See the following section about survival factor for more details.
Coupon	The coupon payable on an investment in this MBS. Enter this parameter as a proportion, *for example*, enter 0.05 for 5%.
OASMortgages	The option adjusted spread of the mortgage pool, in basis points.
PSASpeed	The rate of the deterministic part of unscheduled prepayment, expressed as a proportion of the US Public Securities Association (PSA) (now the Securities Industry and Financial Markets Association) prepayment schedule. *For example*, an input of 0.9 represents 90% of the PSA benchmark. The maximum parameter value is 16.66, because this value results in the entire pool of loans refinancing.
RequiredGainDistribution	This parameter defines the parameters of the individual groups of underlying mortgages in terms of the refinancing costs associated with refinancing and the distribution of gains they require before they consider refinancing. Each row in the RequiredGainDistribution represents a group, and groups can be added or deleted as required. The distribution of required gains for each group is modeled as a truncated normal distribution, with parameters are defined as follows: • **Description**—A string identifier for the group. This exact string description must be used in the AvailableGain, ProportionRefinancing, and RemainingProportion outputs. • **Weight**—The weightings of the groups making up the MBS. The weightings of all groups must sum to 1.0. • **RelativeMeanGain**—A component of the mean of the normal distribution that depends on the outstanding balance. • **AbsoluteMeanGain**—An absolute component of the mean of the normal distribution. • **ARMsInclination**—The component of the mean of the normal distribution contributing the inclination of mortgage holders to refinance into adjustable rate mortgages. • **StandardDeviation**—The standard deviation of the underlying normal distribution.

Name	Description
	• **VariableRefinanceCost**—Refinancing costs that are proportional to the outstanding balance at the time of refinancing. Expressed as a proportion. • **FixedRefinanceCost**—Refinancing costs that are fixed, regardless of the outstanding balance of the underlying mortgages. Expressed as a proportion. • **HitRatio**—The hit ratio describes the maximum proportion of the mortgage pool that can refinancing over a period of one year, if favorable refinancing conditions exist for the full year. If finer time steps are used, then the maximum proportion is adjusted consistently.
PrevailingSpotRateTerm	When the Prevailing Rate strategy is used, this input defines the term of the prevailing spot rate that is used to derive the Coupon and MortgageCoupon.
CouponSpread	When the Prevailing Rate strategy is used, this input defines the coupon as a spread above the prevailing annually compounded spot rate of term equal to PrevailingSpotRateTerm. $\text{Coupon} = \text{PrevailingSpotRate} + \text{CouponSpread}$
MortgageCouponSpread	When the Prevailing Rate strategy is used, this input defines the mortgage coupon as a spread above the prevailing annually compounded spot rate of term equal to PrevailingSpotRateTerm. $\text{MortgageCoupon} = \text{PrevailingSpotRate} + \text{MortgageCouponSpread}$
EnableNegativeCoupons	Specify whether coupons are allowed to take negative values.

Outputs

Name	Description
Value	The value of the asset. This output is the option-adjusted sum of discounted expected future cash flows and is after any refinancing and/or rebalancing have been taken into account.
Price	The price of the asset on a "per unit outstanding balance" basis, defined as $\text{Price}(t) = \frac{\text{Value}(t)}{\text{Balance}(t)}$
TotalReturn	The total return earned over the time interval. This output is the net result of any changes in value of the MBS as well as the value of reinvestment of cash flows. $\text{TotalReturn}(t) = \frac{(\text{ValuePreRebalancing}(t) + \text{TotalCashflow}(t))}{\text{Value}(t - \Delta t)} - 1$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place. **Note** If you choose to output the TotalReturn less frequently than every time step, then the software calculates it from the total return index as: $\text{TotalReturn}(t') = \frac{\text{TotalReturnIndex}(t')}{\text{TotalReturnIndex}(t' - \Delta t')} - 1$ where t' is a time where data is output, and $\Delta t'$ is the time between the current and the previous output.
TotalReturnIndex	The total return index of the MBS. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex (0) = 1.
ExcessReturn	The return earned on the asset in excess of the risk free return.

Name	Description
ExcessReturnIndex	The excess return index of the asset. The software calculates this output using the following equation. $$\text{ExcessReturnIndex}(t) = \text{ExcessReturnIndex}(t-\Delta t) \times (1 + \text{ExcessReturn}(t))$$ where ExcessReturnIndex(0) = 1.
CapitalChange	The change in capital value over the time step, calculated as: $$\text{CapitalChange}(t) = \frac{\text{ValuePreRebalancing}(t)}{\text{Value}(t-\Delta t)} - 1$$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place. If the file output is not every time step then it is recalculated from an index so as to represent the capital change since the previous time step that is actually output.
IncomeReturn	The component of return due to income, where all of the cash flows are treated as income. $$\text{IncomeReturn}(t) = \frac{\text{TotalCashflow}(t)}{\text{Value}(t-\Delta t)}$$
TotalCashflow	The net cash flow received over the course of this time step. This output has four components: $$\text{TotalCashFlow}(t) = \text{Interest}(t) + \text{Principal}(t) + \text{Prepayment}(t) + \text{Refinancing}(t)$$
Interest	The component of the total cash flow received over this time step that is due to interest payments.
Principal	The component of the total cash flow received over this time step that is due to scheduled principal repayments.
Prepayment	The component of the total cash flow received over this time step that is due to any curtailment, unscheduled prepayment, or complete loan refinancing that is not correlated to interest rate movements.
RefinancingCashflow	The component of the total cash flow received over this time step due to complete mortgage refinancing that is correlated to interest rate movements.
Balance	The proportion of the initial mortgage balance that is outstanding at the end of this time period.
Nominal	The number of units of this asset that are held. This output can change on rebalancing which mimics the action of selling the holding and buying a new asset with the proceeds. Depending on the value of the new asset, we might be able to buy more than (or less than) one unit of the new asset. The software calculates this output using the following equation. $$\text{Nominal}(t) = \text{Nominal}(t-\Delta t) \times \frac{\text{ValuePreRebalancing}}{\text{Value}(t)}$$ where ValuePreRebalancing(t) is the value at this time step immediately before any rebalancing that might take place.
Coupon	The coupon value that is actually being applied for the next time step. This output can vary over time when the Prevailing Rate rebalancing strategy is used.
MortgageCoupon	The mortgage coupon value that is actually being applied for the next time step. This output can vary over time when the Prevailing Rate rebalancing strategy is used.
ReinvestmentValue	The total value of the reinvestment in the FRN submodel. This output is only used with the **FRN Reinvestment Buy And Hold** strategy.
AvailableGain [Description]	The gain available for refinancing for the group with label **Description**. **Description** must match exactly the description given for this group in the required gain distribution.

Name	Description
ProportionExercising [Description]	The proportion of the remaining mortgage holders in this group. **Description** must match exactly the description given for this group in the required gain distribution.
RemainingProportion [Description]	The proportion of the initial mortgage balance that remains in the group with label **Description**. **Description** must match exactly the description given for this group in the required gain distribution.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index for all trials and takes the average.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average.

FRN

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A floating rate bond that can be used for reinvesting cash flows of its parent DanishMBS only (and only if the MBS uses the FRN reinvestment strategy). This FRN is not subject to default. In addition, the FRN is rebalanced each time step into an FRN with the maturity as input. In this regard, it is different to the full feature FRN model available under bond issuers.

Input variables

Name	Description
Maturity	The term to maturity (in years) of the FRN.
Margin	The fixed margin over the risk free rate that is paid on this FRN. Enter this parameter as a proportion, *for example*, enter 0.01 for a 1% (100 bp) margin.
CouponFrequency	The frequency of coupon resets (and coupon payments) on the FRN. Enter this parameter as a number per annum. The parameter is constrained to be equal to the simulation time step so that exactly one coupon is received each time step.

Outputs

Name	Description
Price	The price of the FRN.
TotalReturn	The simply compounded total return earned over the time interval. This output is the net result of capital changes and coupons received.

Survival Factor versus Pool Factor

Note the widely accepted definition of pool factor, which is the proportion of the original balance that is outstanding. Since the loan is amortizing the outstanding balance naturally reduces over time, even when there are no unscheduled payments. The survival factor takes account of unscheduled payments only, meaning that if there are no unscheduled payments over a given period the survival factor remains constant.

To convert from a pool factor to a survival factor that is suitable for input here, divide the pool factor by the scheduled remaining balance for mortgages at the input value of Age. This scheduled remaining balance (assuming no unscheduled payments at all) is given by the following equation.

$$\mathrm{ScheduledRemainingBalance} = \frac{1-(1+b)^{-\mathrm{RemainingTerm}\times\mathrm{MtgeCouponFreq}}}{1-(1+b)^{-\mathrm{MtgeTerm}\times\mathrm{MtgeCouponFreq}}}$$

where

$$b = \frac{\mathrm{Mtgecoupon}}{\mathrm{MtgeCouponFreq}}$$

and the remaining term in years is defined in terms of the Age by:

$$\mathrm{RemainingTerm} = \mathrm{MtgeTerm} - \frac{Age}{12}$$

G2CreditStatisticalSpreadIssuer

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

An organization issuing bonds.

Addable submodels

Name	Description	Availability
G2CreditStatisticalSpreadBond	G2 credit statistical spread bond.	RSG

Input variables

Name	Description	Conditions
CreditModel	Select the credit model, of the G2CreditStatisticalSpreadModel type, for the credit migration calculation.	
EquityRiskDriver	Select a risk driver from the ones that you have defined. Cannot be a NonCentralChiSquaredRiskDriver, EmpiricalRiskDriverAutoCorrelatated, ParetoCompoundPoissonRiskDriverAutoCorrelated, GammaRiskDriverAutoCorrelated, or PoissonRiskDriverAutoCorrelated.	Enabled only if **UseMultipleRiskDrivers** is **False**.

Name	Description	Conditions
UseEquityRiskShift	Select **True** to use a ShiftRiskDriver, or **False** not to use a ShiftRiskDriver.	Enabled only if **UseMultipleRiskDrivers** is **False**.
ShiftRiskDriver	Select a risk driver to use as an equity risk shift, from the ones that you have defined. Cannot be a NonCentralChiSquaredRiskDriver, or a PoissonRiskDriverAutoCorrelated.	Enabled only if **UseEquityRiskShift** is **True**.
Correlation	The linear correlation assumption between the credit default shock and equity risk.	Enabled only if **UseMultipleRiskDrivers** is **False**.
MigrationScaler	The scaling factor to apply to the correlation assumption, to give the correlation between credit migration and equity risk.	Enabled only if **UseMultipleRiskDrivers** is **False**.
ProbabilityOfDefault	The probability of default.	
CreditExposure	The estimated credit exposure of the counterparty.	
LGD	The loss given default.	
UseMultipleRiskDrivers	Select **True** to specify multiple risk drivers, or **False** to use a single equity risk driver.	
MultipleRiskDrivers	Select the risk drivers that you want to use. For each risk driver, enter the following: • **RiskDriver**—The risk driver to use. Cannot be a NonCentralChiSquaredRiskDriver. • **Correlation**—The linear correlation assumption between the credit default shock and risk driver used. • **MigrationScalar**—The scaling factor to apply to the correlation assumption, to give the correlation between credit migration and risk driver used.	Enabled only if **UseMultipleRiskDrivers** is **True**.
MigrationShockVolatility	The volatility to use to calculate the migration shock.	Enabled only if **UseMultipleRiskDrivers** is **True**.
DefaultShockVolatility	The volatility to use to calculate the default shock.	Enabled only if **UseMultipleRiskDrivers** is **True**.

Outputs

Name	Description
SystematicRisk	If **UseMultipleRiskDrivers** is **True**, then the systematic risk is the sum of the variates of the risk factors in **MultipleRiskDrivers**. If **UseMultipleRiskDrivers** is **False**, then the systematic risk is the standardized normal realization of the equity risk driver, combined with a risk driver where applicable. If **UseEquityRiskShift** is **False**, calculated as $\mathrm{SystematicRisk} = \mathrm{EquityRiskDriver.Variate}$ If **UseEquityRiskShift** is **True**, calculated as $\mathrm{SystematicRisk} = \mathrm{StandardNormal.InverseCDF}(\mathrm{EquityRiskDriver.CDF}(\mathrm{EquityRiskDriver.Value} + \mathrm{ShiftRiskDriver.Value}))$

Name	Description
MigrationShock	The shock that determines whether a security migrates to a new credit state. If **UseMultipleRiskDrivers** is **True,** calculated as a sum over k risk drivers specified in **MultipleRiskDrivers.** $$\text{MigrationShock} = -\sum_{k=1}^{N}(Z_k \times \rho_k \times \gamma_k) + \varepsilon^M \sigma^M$$ where: • Z_k is the variate for risk driver *k.* • ρ_k is the Correlation. • γ_k is the MigratorScaler. • ε^M is an independent standard normal shock. • σ^M is the MigrationShockVolatility. If **UseMultipleRiskDrivers** is **False,** calculated as $$\text{MigrationShock} = -Z \times \rho \times \gamma + \varepsilon^M \sqrt{1 - \rho^2 \gamma^2}$$ where: • Z is the SystematicRisk. • ρ is the Correlation. • γ is the MigratorScaler. • ε^M is an independent standard normal shock.
DefaultShock	The shock that determines whether a security defaults. If **UseMultipleRiskDrivers** is **True,** calculated as a sum over k risk drivers specified in **MultipleRiskDrivers.** $$\text{DefaultShock} = -\sum_{k=1}^{N}(Z_k \times \rho_k) + \varepsilon^D \sigma^D$$ where: • Z_k is the variate for risk driver *k.* • ρ_k is the Correlation. • ε^D is an independent standard normal shock. • σ^D is the DefaultShockVolatility. If **UseMultipleRiskDrivers** is **False,** calculated as $$\text{DefaultShock} = -Z \times \rho + \varepsilon^D \sqrt{(1 - \rho^2)}$$ where: • Z is the SystematicRisk. • ρ is the Correlation. • ε^D is an independent standard normal shock.
CreditDefaultLoss	The loss on default.

G2CreditStatisticalSpreadBond

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

G2 credit statistical spread bond.

Input variables

Name	Description
CreditClass	The initial credit class of the security.

Outputs

Name	Description
CreditClass	The credit class of the security, as a string.
SpreadChangeAverage	The spread change of the credit class rating, averaged over the current and previous time step.

4.3 Derivatives

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Derivative assets are grouped into several types and there is a container for each type here.

Containers

Name	Description
EquityOptions	This container holds all the equity option contracts.
Swaps	This container holds all the swaps contracts.
Swaptions	This container holds all the swaption contracts.
Forwards	This container holds all the forward contracts.

All of the derivatives are not suitable for risk neutral modeling and are not expected to pass martingale tests.

Note To price assets using a swap nominal yield curve, create your yield curve, and select it as the pricing curve in the asset definition.

4.3.1 EquityOptions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Container for put and call options.

Addable submodels

Name	Description
EquityPutOption	Equity put option.
EquityCallOption	Equity call option.

EquityPutOption

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Equity Put Options are modeled using Black-Scholes formulae.

Input variables

Name	Description	Conditions
UnderlyingEquityAsset	The underlying equity asset on which the option is written.	
PricingCurve	The nominal yield curve, from the economy of the underlying equity asset, that you want to use to price the option.	Enabled after you select an **UnderlyingEquityAsset**.
Strike	The strike price of the equity option, expressed as a percentage of the current equity market level.	
Volatility	The Black-Scholes implied volatility used to price the option.	
Maturity	The time to maturity of the option, in years.	

Outputs

Name	Description
Price	The price of one unit of the equity put option.
Cashflows	The monetary cash flow arising from the put option from time step t-dt to t.

EquityCallOption

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Equity Call Options are modeled using Black-Scholes formulae.

Input variables

Name	Description	Conditions
UnderlyingEquityAsset	The underlying equity asset on which the option is written.	
PricingCurve	The nominal yield curve, from the economy of the underlying equity asset, that you want to use to price the option.	Enabled after you select an **UnderlyingEquityAsset**.
Strike	The strike price of the equity option, expressed as a percentage of the current equity market level.	
Volatility	The Black-Scholes implied volatility used to price the option.	
Maturity	The time to maturity of the option, in years.	

Outputs

Name	Description
Price	The price of one unit of the equity call option.
Cashflows	The monetary cash flow arising from the put option from time step t-dt to t.

4.3.2 Swaps

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Addable submodels

Name	Description
ZeroCouponInflationSwap	Zero coupon inflation for fixed swap.
ZeroCouponNominalSwap	Zero coupon fixed for floating swap.
GenericSwap	Coupon paying fixed/floating for fixed/floating multiple economy swap.

ZeroCouponYearOnYearLPISwap

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

This model simulates the behavior of a zero coupon year-on-year limited price indexation swap. For more information, see van Bezooyen, Exley & Smith (1997), *A Market Based Approach to Valuing LPI Liabilities*.

Input variables

Name	Description
Economy	The economy in which the swap is denominated.
RemainingTerm	The remaining term to maturity.
TermInForce	The term that the swap has already been in-force for. **Note** The total swap term is TermInForce + RemainingTerm.
FixedLeg	The rate of the fixed leg of the swap. If this input is set to 0, the fixed leg is calculated so that the initial swap value at outset is zero.
Cap	The annualized cap that is placed on the swap over the full term of the swap.
Floor	The annualized floor that is placed on the swap over the full term of the swap.
LPIIndexToDate	The cumulative LPI index, assumed to be 1 at swap initiation.
UnappliedInflation	The increase/decrease in inflation since the last LPI increase was evaluated.
InflationRates	The inflation model that you want to use in the valuation of the swap as the expected break-even inflation rate.
ReferenceIndex	The inflation index that you want to use in the valuation of the swap to represent realized inflation.

Outputs

Name	Description
Price	The market value of the swap at time step *t* per unit nominal.
Income	The net income arising from the swap over the time step per unit nominal.
FixedLeg	The fixed leg under the swap.
FloatingLegValue	The market value of the floating leg of the swap at time step *t* per unit nominal.
FixedLegValue	The market value of the fixed leg of the swap at time step *t* per unit nominal.
LPIIndex	The year-on-year LPI Index at time step *t*, assumed to be 1 at swap initiation.
PV01	The change in the present value of the swap caused by a one basis point parallel shift in the yield curve.

Name	Description
IE01	The change in the present value of the swap caused by a one basis point parallel shift in the breakeven inflation curve.

ZeroCouponInflationSwap

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Inflation swaps are modeled in the software with a cash flow structure that mimics the fundamental over-the-counter characteristics — that is, without the continual mark-to-market that is typical in futures markets.

The contract is set up with a fixed leg, which you can choose, or have the software determine the value that produces a "fair" (zero value) swap contract at inception. Thereafter, a cash flow only takes place when the contract matures, because (as labeled) these are zero-coupon inflation swaps. For this reason, the Income output, which represents cash flows from the contract, only has a non-zero value at the time step in which the swap contract matures.

There is a difference between market-consistent inflation projections (often called "breakeven inflation") and the inflation that is expected under real-world probabilities, which is also different from experienced inflation. For pricing purposes (to price the inflation swap), we need the market-consistent value, which is determined from the nominal and real ZCBPs with the relevant maturities.

Input variables

Name	Description
Economy	The economy in which the swap is denominated.
RemainingTerm	The remaining term to maturity.
TermInForce	The term which the swap has already been in force. The total swap term is TermInForce + RemainingTerm.
FixedLeg	The rate of the fixed leg of the swap. If this parameter is set to zero, the fixed leg is calculated so that the initial swap value at outset is zero.
InflationIndexToDate	The cumulative inflation index, assumed to be 1.0 at swap initiation.
InflationRates	The inflation model that you want to use in the valuation of the swap as the expected break-even inflation rate.
ReferenceIndex	The inflation index that you want to use in the valuation of the swap to represent realized inflation.

Outputs

Name	Description
Price	The market value of the swap per unit nominal for the party paying fixed and receiving floating. $\mathrm{Price}(t) = \mathrm{FloatingLegValue}(t) - \mathrm{FixedLegValue}(t)$.

Name	Description
Income	The net income arising from the swap per unit nominal. The Income output is zero except at the time step when the contact matures. It is calculated as follows: $\text{Income}(t) = \text{InflationIndex}(t) - (1 + \text{FixedLeg})^{\text{Term}}$ where $\text{Term} = \text{RemainingTerm} + \text{TermInForce}$ is the total swap term at initiation.
FixedLeg	The fixed rate under the swap that was agreed at the inception of the contract (this is the same at each time step). This can be reproduced as: $\text{FixedLeg} = \left(\text{InflationIndex}(0) \times \frac{\text{RealZCBP}(\text{Govt}, \text{RemainingTerm}, \text{Seniority}, 0)}{\text{NominalZCBP}(\text{Govt}, \text{RemainingTerm}, \text{Seniority}, 0)} \right)^{\text{Term}} - 1$ where: • RealZCBP(Govt, RemainingTerm, Seniority, 0) is the riskless real yield curve zero coupon bond price at time zero (seniority is not important as it is riskless) • NominalZCBP(Govt, RemainingTerm, Seniority, 0) is the riskless nominal yield curve zero coupon bond price at time zero, and • $\text{Term} = \text{RemainingTerm} + \text{TermInForce}$ is the total swap term at initiation.
FloatingLegValue	The market value of the floating leg of the swap per unit nominal. $\text{FloatingLegValue}(t) = \text{InflationIndex}(t) \times \text{RealZCBP}(\text{Govt}, \text{RemainingTerm} - t, \text{Seniority}, t)$ where: • RealZCBP(Govt, RemainingTerm - t, Seniority, t) is the riskless real yield curve zero coupon bond price at this time step (seniority is not important as it is riskless) for the time remaining until maturity • $\text{Term} = \text{RemainingTerm} + \text{TermInForce}$ is the total swap term at initiation.
FixedLegValue	The market value of the fixed leg of the swap per unit nominal. $\text{FixedLegValue}(t) = \text{NominalZCBP}(\text{Govt}, \text{RemainingTerm} - t, \text{Seniority}, t) \times (1 + \text{FixedLeg}(t))^{\text{Term}}$ where: • NominalZCBP(Govt, RemainingTerm - t, Seniority, t) is the riskless nominal yield curve zero coupon bond price at this time step (seniority is not important as it is riskless) for the time remaining until maturity • $\text{Term} = \text{RemainingTerm} + \text{TermInForce}$ is the total swap term at initiation.
InflationIndex	The cumulative inflation index, assumed to be 1.0 at swap initiation. This output is equal to the InflationIndex from the inflation model scaled by the InflationIndexToDate input to this asset.

ZeroCouponNominalSwap

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Fixed for floating zero coupon swap.

Input variables

Name	Description	Conditions
Economy	The economy in which the swap is denominated.	
PricingCurve	The nominal yield curve that you want to use to price the swap.	Enabled after you select an **Economy**.
RemainingTerm	The remaining term to maturity.	
FloatingNotionalToDate	The current value of the swap floating notional. That is, the floating notional at outset plus accumulated interest. If set to zero, a floating notional is calculated to set the initial swap value at outset to zero.	

Outputs

Name	Description
Price	The market value of the swap per unit nominal. $\text{Price}(t) = \text{FixedLegValue}(t) - \text{FloatingLegValue}(t)$
Income	The net income arising from the swap over the time step per unit nominal. The Income output is zero except at the time step when the contact matures. $\text{Income}(t) = (1 - \text{FloatingNotional}(t) \times \text{NominalRateIndex}(t)) \times (1 + \text{Rate}(t))$ where: $\text{Income}(0) = 0$ $\text{Rate}(t) = \dfrac{\text{NominalZCBP}(\text{Govt}, \text{RemainingTerm}(t) + dt, \text{Seniority}, t-1)}{\text{NominalZCBP}(\text{Govt}, dt, \text{Seniority}, t-1)}$ • NominalZCBP(Govt, *T*, Seniority, *t*) is the riskless nominal yield curve zero coupon bond price at time *t* with maturity *T*.
FloatingLegValue	The market value of the floating leg of the swap per unit nominal. $\text{FloatingLegValue}(t) = \text{FloatingLegValue}(t-1) \times (1 + \text{NominalYieldCurve.CashTotalReturn}(t))^{\min\left(\frac{\text{RemainingTerm}(t)}{dt}, 1\right)}$
FixedLegValue	The market value of the fixed leg of the swap per unit nominal. $\text{FixedLegValue}(t) = \left(\begin{array}{c} 1 + \text{NominalYieldCurve.SpotRate} \\ (\text{Govt}, \text{RemainingTerm}(t), \text{Seniority}, t) \end{array}\right)^{-\text{RemainingTerm}(t)}$ where if FloatingNotional = 0 then $\text{FloatingLegValue}(0) = \text{FixedLegValue}(0)$
FloatingNotional	The floating notional under the swap. That is, Floating Notional at outset plus accumulated interest.
NomRateIndex	The index of the floating leg rollup to date.

GenericSwap

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Fixed/floating for fixed/floating multi-economy coupon paying swap. The receive side of the swap is assumed to have unit principal.

Input variables

Name	Description	Conditions
PayEconomy	The economy in which the pay side of the swap is denominated.	
PayPricingCurve	The nominal yield curve that you want to use to price the pay side of the swap.	Enabled after you select a **PayEconomy**
PayType	The leg type of the pay side of the swap. Select Fixed or Floating.	
PayCouponFreq	The frequency of coupons per annum on the pay side of the swap.	
PayRate	The rate which is in force on the pay side of the swap (if this rate is known). If the pay side is a fixed leg, input 0 to set the fixed rate so that the pay side is valued at par. Using 0 results in a zero value for the swap provided the receive side is also valued at par.	
ReceiveEconomy	The economy in which the receive side of the swap is denominated.	
ReceivePricingCurve	The nominal yield curve that you want to use to price the receive side of the swap.	Enabled after you select a **ReceiveEconomy**
ReceiveType	The leg type of the receive side of the swap. Select Fixed or Floating.	
ReceiveCouponFreq	The frequency of coupons per annum on the receive side of the swap.	
ReceiveRate	The rate which is in force on the receive side of the swap (if this rate is known). If the receive side is a fixed leg, input 0 to set the fixed rate so that the receive side is valued at par. Using 0 results in a zero value for the swap provided the pay side is also valued at par.	
Term	The remaining term to maturity of the swap (from the start of the simulation).	
ExchangeRateAtInitiation	The exchange rate at initiation of the swap (only necessary if the swap is already in force) expressed as receiver/payer. This rate is used to set the relative principal on the pay side of a cross-currency swap so that the swap has zero value if both legs are valued at par: $$\mathrm{ExchangeRateAtInitiation} \times \mathrm{PaySidePrincipal} = 1.$$ The actual time of initiation of the swap (that is, the time at which the exchange rate applies) is not required to be known to calculate the pay side principal. **Note** If this parameter is set to zero, then the exchange rate is determined based on the simulation.	

Outputs

Name	Description
Price	The value of the swap at the time step as a proportion of holding, denominated in the receive side currency.
Income	The net income from the swap over the time step as a proportion of holding, denominated in the receive side currency.
PayerLegValue	The value of the pay side of the swap at the time step as a proportion of holding, denominated in the receive side currency.
ReceiverLegValue	The value of the receive side of the swap at the time step as a proportion of holding, denominated in the receive side currency.
PaySideIncome	The income from the pay side of the swap over the time step as a proportion of holding, denominated in the pay side currency.
ReceiveSideIncome	The income from the receive side of the swap over the time step as a proportion of holding, denominated in the receive side currency.

ForwardGenericSwap

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Fixed/floating for fixed/floating multi-economy coupon paying swap.

Input variables

Name	Description	Conditions
PayCouponFreq	The frequency that coupons are paid per year.	
PayEconomy	The economy the pay side of the swap is denoted in.	
PayPricingCurve	The nominal yield curve that you want to use to price the pay side of the swap.	Enabled after you select a **PayEconomy**
PayType	The type of the pay side of the swap. Select **Fixed** or **Floating**.	
PayRate	The rate of the pay side of the swap if this is known, inputting 0 for PayRate and ReceiveRate will set the rate of the Swap to give a zero value.	
ReceiveCouponFreq	The frequency that coupons are received per year.	
ReceiveEconomy	The economy the receive side of the swap is denoted in.	
ReceivePricingCurve	The nominal yield curve that you want to use to price the receive side of the swap.	Enabled after you select a **ReceiveEconomy**
ReceiveType	The type of the receive side of the swap. Select **Fixed** or **Floating**.	

Name	Description	Conditions
ReceiveRate	The rate of the receive side of the swap if this is known, inputting 0 for PayRate and ReceiveRate will set the rate of the Swap to give a zero value.	
Term	The remaining term to maturity of the swap.	
DeferralTerm	The time until the swap initiates in years.	
ExchangeRateAtInitiation	The exchange rate at initiation of the swap.	

Outputs

Name	Description
Price	The price of the swap to the receive side. This is denominated in the currency of the receiving side.
Income	The net income from the swap due to the receive side. This is denominated in the currency of the receiving side.
PayerLegValue	The value of the pay side of the swap.
ReceiverLegValue	The value of the receive side of the swap.
PaySideIncome	The income from the pay side.
ReceiveSideIncome	The income from the receive side.
PV01	The change in the present value of the swap caused by a one basis point parallel shift in the yield curve.
IE01	The change in the present value of the swap caused by a one basis point parallel shift in the breakeven inflation curve.

4.3.3 Swaptions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Container for swaptions.

Addable submodels

Name	Description
RealSwaption	Inflation for fixed swaption.
NominalSwaption	Fixed for floating swaption.

RealSwaption

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A Gaussian model variation is used to price real interest rate swaptions.

Input variables

Name	Description
Economy	The economy in which the swaption is denominated.
Strike	The spot interest rate strike of the swaption.
Volatility	The absolute implied volatility of the underlying forward swap rate. Under this model, the volatility of the underlying forward swap rate is an absolute volatility, rather than a proportional volatility.
SwapPosition	Selects whether the swaption is a receive-fixed or payer swaption.
OptionMaturity	The term to maturity of the option.
SwapTenor	The term of the swap on which the option is written.
Frequency	The frequency of payments under the swap on which the option is written.
InflationRates	The inflation model that you want to use in the valuation of the swaption as the expected break-even inflation rate.
ReferenceIndex	The inflation index that you want to use in the valuation of the swaption to represent realized inflation.

Outputs

Name	Description
Value	The value of the swaption per unit of nominal.
Income	The income arising from the swaption per unit nominal.
ForwardSwapRate	The forward swap rate underlying the swaption.
AnnuityRate	The value of an annuity certain paying one unit per annum according to the payment frequency specified in the input.

NominalSwaption

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The Black (1976) model is used to price swaptions at each time step.

Input variables

Name	Description	Conditions
Economy	The economy in which the swaption is denominated.	
PricingCurve	The nominal yield curve that you want to use to price the swaption.	Enabled after you select an **Economy**.
Strike	The spot interest rate strike of the swaption.	
Volatility	The absolute implied volatility of the underlying forward swap rate. Under this model, the volatility of the underlying forward swap rate is an absolute volatility, rather than a proportional volatility.	
SwapPosition	Selects whether the swaption is a receive-fixed or payer swaption	
OptionMaturity	The term to maturity of the option.	
SwapTenor	The term of the swap on which the option is written.	
Frequency	The frequency of payments under the swap on which the option is written.	

Outputs

Name	Description
Value	The value of the swaption per unit of nominal.
Income	The income arising from the swaption per unit nominal.
ForwardSwapRate	The forward swap rate underlying the swaption.
AnnuityRate	The value of an annuity certain paying one unit per annum according to the payment frequency specified in the input.
PV01	The change in the present value of the swaption caused by a one basis point parallel shift in the yield curve.
IE01	The change in the present value of the swaption caused by a one basis point parallel shift in the breakeven inflation curve.

4.3.4 Forwards

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A container for forward contracts.

Addable submodels

Name	Description
Forward	Forward contract.

Forward

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

It is assumed that all contracts settle for cash at maturity. All forward contracts are total return contracts.

Input variables

Name	Description	Condition
UnderlyingAsset	The asset underlying the forward contract.	
PricingCurve	The nominal yield curve, from the economy of the underlying asset, that you want to use to price the forward contract.	Enabled after you select an **UnderlyingAsset**
Position	Specifies whether the forward contract is long or short.	
Maturity	The term to maturity of the forward contract in years.	
ForwardPrice	The agreed forward delivery price of the underlying asset at maturity, expressed as a proportion of the current asset price. If this input is 0, ForwardPrice is automatically calculated so that the value of the contract at outset is zero. **Note** The time 0 price for all assets except specific bonds is 1. The time 0 price of specific bonds is the actual discounted cash flow value.	

Outputs

Name	Description
Price	The value of the forward contract.
Cashflows	The cash flow occurring over the previous time interval.
ForwardPrice	The agreed forward delivery price of the underlying asset at maturity.

4.4 Parser

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The asset parser model reads in externally calculated prices and cash flows to give you extra flexibility in defining assets. The values are read in from an external .csv file. The Parser node itself has no inputs or outputs. It is merely a container for the addable asset parser models.

Addable submodels

Name	Description
AssetParser	This model enables you to define assets by defining cash flow and price for every trial and time step.

4.4.1 AssetParser

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Asset parser.

Input variables

Name	Description
Economy	The economy in which the Parser is denominated.
Datafile	The location of the data file that contains the input information. For information about the file format, see AssetParser File Format.

Outputs

Name	Description
Price	The price of one unit of holding of the asset.
Cashflow	The cash flow from the asset during time step t-dt to t.
TotalReturn	The total return of the asset over the time step.
TotalReturnIndex	The total return index of the asset. $\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t - \Delta t) \times (1 + \mathrm{TotalReturn}(t))$ where: $\mathrm{TotalReturnIndex}(0) = 1$
CapitalChange	The TotalReturn minus the IncomeReturn.

Name	Description
CapitalIndex	The capital index of the asset. $\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$ where: $\text{CapitalIndex}(0) = 1.0$
IncomeReturn	Cash flow expressed as a proportion of the value of the portfolio at the start of the time step.

AssetParser File Format

For k time steps, an asset parser file takes the form:

File format

Column 1	Column 2	Column 3	Column 4
Trial,	Timestep,	Cashflow,	Price,
1	0,	data_1,	data_2,
1	1,	data_1,	data_2,
1	2,	data_1,	data_2,
1	...,	data_1,	data_2,
1	k,	data_1,	data_2,
2	0,	data_1,	data_2,
2	1,	data_1,	data_2,
2	...,	data_1,	data_2,
2	k,	data_1,	data_2.

The column headers and order are not optional, and there must be data present for each row and column for each trial and time step required.

Note The parser file culture must match the culture settings of the machine running the simulation.

4.5 Funds

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This container holds unit funds.

Addable submodels

Name	Description
UnitFund	A portfolio of asset types. The portfolio can contain combinations of the following asset types: • Equity assets • Fixed income assets • Derivative assets • Asset parsers • Other unit funds

4.5.1 UnitFund

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

You can use a unit fund to model different asset types as one combined portfolio. The unit fund asset can accommodate combinations of:

- Equity assets
- Fixed income assets
- Derivative assets
- Asset parsers
- Other unit funds

The fund can be currency hedged, and rebalanced. Rebalancing is limited to initial proportion rebalancing and excludes any derivative assets in the fund.

You can also specify limits for leveraging. If the maximum or minimum leverage limit is breached, the fund makes a cash call. The amount of the cash flow is that required to return the fund to the TargetLeverage that you specify. If you have unit funds in a unit fund, the parent unit fund cannot use leveraging.

Input variables

Name	Description	Condition
Economy	Specify the base currency of the fund.	
Holdings	Specify the asset instruments and holdings that make up the unit fund. Negative holdings of assets are allowed, but the fund must maintain an overall net long position at all points in the projection. If this is not the case, a runtime error occurs and you must change your asset holdings for the simulation to run successfully.	
InputType	From the drop-down list, select the type of inputs. Possible values: • **Unit**—Nominal units.	

Name	Description	Condition
	• **Market value** The software uses this variable to convert the values that you enter in **Holdings** into initial nominal unit holdings for each of the non-derivative assets in the fund. For any derivative assets in the portfolio, the value in **Holdings** always refers to nominal units, regardless of the **InputType** that you select.	
Rebalancing	The rebalancing method. Possible values: • **Buy and hold**—If you select **Buy and hold**, initial unit holdings are calculated and maintained throughout the projection, unless adjusted for currency hedging. • **Initial Proportion**—If you select **Initial Proportion**, the software calculates the nominal unit holdings of asset instrument *i* at time *t* as shown in the following equation. $$\text{Holdings}_t^i = \frac{\text{ExchangeRateNominal}_t^i}{\text{ExchangeRateNominal}_t^{UF}} \times \text{FundPhysicalValue}_t \times \frac{\text{Holdings}_0^i \times \text{Price}_0^i \times \frac{\text{ExchangeRateNominal}_t^i}{\text{ExchangeRateNominal}_t^{UF}}}{\text{Time0PhysicalValue}_t \times \text{Price}_t^i}$$ where: • Holdings_t^i is the nominal unit holdings of asset instrument *i* at time step *t* • $\text{ExchangeRateNominal}_t^{UF}$ and $\text{ExchangeRateNominal}_t^i$ are the price at time *t* of one unit of the simulation base currency in units of the economy of the unit fund and asset instrument *i* respectively. • $\text{FundPhysicalValue}_t$ is the value at time *t* of the non-derivative assets in the fund, calculated as shown in the following equation. $$\text{FundPhysicalValue}_t = \sum_{\forall i (\text{InstrumentType} \neq \text{Derivative})} \text{Holdings}_t^i \times \text{Price}_t^i \times \frac{\text{ExchangeRateNominal}_t^{UF}}{\text{ExchangeRateNominal}_t^i}$$ • $\text{Time0PhysicalValue}_t$ is the value at time 0 of the non-derivative assets which still exist, that is, have not matured, at time *t*, calculated as shown in the following equation. $$\text{Time0PhysicalValue}_t = \sum_{\forall i \text{ existing at time } t (\text{InstrumentType} \neq \text{Derivative})} \text{Holdings}_0^i \times \text{Price}_0^i \times \frac{\text{ExchangeRateNominal}_0^{UF}}{\text{ExchangeRateNominal}_0^i}$$ • Price_t^i is the price of asset instrument *i* at time *t*.	

Name	Description	Condition
CurrencyHedge	Specify whether the currency is hedge. If you select to hedge currency, then the nominal unit holdings of asset instrument *i* at time *t* are calculated as shown in the following equation. $$\text{Holdings}_t^i = \text{Holdings}_{t-1}^i \times \left(\begin{array}{c} (1 - \text{HedgeRatio}) \\ +\text{HedgeRatio} \times \text{CurrencyHedgeReturn}_t^i \end{array} \right)$$ where: $$\text{CurrencyHedgeReturn}_t^i = \frac{\frac{1+\text{CashTotalReturn}_t^{UF}}{1+\text{CashTotalReturn}_t^i}}{\frac{\text{ExchangeRateNominal}_t^{UF}}{\text{ExchangeRateNominal}_t^i} / \frac{\text{ExchangeRateNominal}_{t-1}^{UF}}{\text{ExchangeRateNominal}_{t-1}^i}}$$ $\text{CashTotalReturn}_t^{UF}$ and $\text{CashTotalReturn}_t^i$ are the total return on cash in the currency of the unit fund and the asset instrument *i* respectively over the time step *t*. The currency hedging calculation uses the nominal yield curve that you specify in Economies.Economy.NominalYieldCurve.CurrencyHedgeCurve.	
HedgeRatio	Specify how much of the currency risk is hedged.	Enabled only if **CurrencyHedge** is **True**.
Leveraged	Specify whether the fund is leveraged. If you set this parameter to **True**, then the software sets up a margin account. In the output, $\text{Value} = \text{Price} - \text{FundingChange}$. **Note** If this unit fund contains another unit fund, then **Leveraged** must be **False**.	
InitialLeverage	Specify the initial leverage of the fund.	Enabled only if **Leveraged** is **True**.
MinLeverage	The minimum leverage that the fund can have. When this limit is breached, *for example*: $$\text{UnleveragedPortfolioValue}_t < \text{MinLeverage} \times \text{MarginAccount}_t$$ then the fund makes a payment to releverage.	Enabled only if **Leveraged** is **True**.
TargetLeverage	The target that the fund is rebalanced to if the minimum or maximum values are breached.	Enabled only if **Leveraged** is **True**.
MaxLeverage	The maximum leverage that the fund can have. When this limit is breached, *for example*: $$\text{UnleveragedPortfolioValue}_t > \text{MinLeverage} \times \text{MarginAccount}_t$$ then the fund makes a payment to releverage.	Enabled only if **Leveraged** is **True**.
ActiveManagement	The active management model for this unit fund.	
InitialIndexValue	The InitialIndexValue for TotalReturnIndex and CapitalIndex outputs.	

Outputs

Name	Description
Price	The price at time step t of the unit fund. For unleveraged funds: $\text{Price}_t = \text{UnleveragedPortfolioValue}_t$ For leveraged funds: $\text{Price}_0 = \frac{\text{UnleveragedPortfolioValue}_t}{\text{InitialLeverage}}$ $\text{Price}_t = \text{Price}_{t-1} + (\text{UnleveragedPortfolioValue}_t - \text{UnleveragedPortfolioValue}_{t-1}) - (\text{UnleveragedPortfolioValue}_{t-1} - \text{Price}_{t-1}) \times \text{CashTotalReturn}_t^{UF} - \text{FundingChange}_t$ When the fund is leveraged, the evolution of the price can be thought of as the price at the previous time step, plus the change in the fund value, minus the cost of borrowing, minus the payment required to return the fund to its target leverage. **Note** If you use active management, the price is updated for the effect of active return.
Payment	The payment produced by the unit fund. Calculated as the total (in the currency of the unit fund) of the individual payments for each of the asset instruments that make up the unit fund, plus the payment required to return the fund to its target leverage. $\text{Payment}_t = \sum_{\forall i} \text{Holdings}_t^i \times \text{Payment}_t^i \times \frac{\text{ExchangeRateNominal}_t^{UF}}{\text{ExchangeRateNominal}_t^i} + \text{FundingChange}_t$ **Note** If you use active management, the price is updated for the effect of active return.
TotalReturn	The total return of the fund earned over the time step. $\text{TotalReturn}(t) = \frac{\text{Price}(t) + \text{Payment}(t)}{\text{Price}(t - dt)} - 1$ where TotalReturn(0) = 0.
TotalReturnIndex	The total return index of the fund. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - dt)(1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = InitialIndexValue.
Leverage	The leverage of the fund at time step t.
UnLeveragedPortfolioValue	The value of the portfolio, excluding any leverage. Calculated as shown in the following equation. $\text{Value}_t = \sum_{\forall i} \text{Holdings}_t^i \times \text{Price}_t^i \times \frac{\text{ExchangeRateNominal}_t^{UF}}{\text{ExchangeRateNominal}_t^i}$
FundingChange	If the fund has breached either the **MaxLeverage** or **MinLeverage** restriction at the time step, then this is the payment that is received or made by the fund to deleverage or releverage at time step t. The payment is equal to the amount needed to return the fund to the **TargetLeverage** specified.

Name	Description
CapitalChange	The change in Price from time step $t - \Delta t$ to t. $$\text{CapitalChange}(t) = \frac{\text{Price}(t)}{\text{Price}(t - \Delta t)} - 1$$ where CapitalChange(0) = 0.
CapitalIndex	The capital index of the unit fund. $$\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalReturn}(t))$$ where CapitalIndex(0) = InitialIndexValue.
ExcessReturn	The return earned on the unit fund in excess of the risk free return. $$\text{ExcessReturn}(t) = \frac{1 + \text{TotalReturn}(t)}{1 + \text{CashTotalReturn}(t)} - 1$$ where ExcessReturn(0) = 0.
ExcessReturnIndex	The excess return index of the unit fund. $$\text{ExcessReturnIndex}(t) = \text{ExcessReturnIndex}(t - \Delta t) \times (1 + \text{ExcessReturn}(t))$$ where ExcessReturnIndex(0) = 1.
IncomeReturn	The income return of the unit fund. $$\text{IncomeReturn}(t) = \text{TotalReturn}(t) - \text{CapitalChange}(t)$$
Duration	For a unit fund with N holdings, each with a duration, $D_i(t)$. The duration of the unit fund, $D^{UF}(t)$, at time t can be calculated as: $$D^{UF}(t) = \sum_{i=1}^{N} D_i(t) \times \frac{V_i(t)}{V^{UF}(t)} \times \frac{X^{UF}(t)}{X_i(t)}$$ $P_i(t)$ is the unit price of asset i. $U_i(t)$ is the number of units of asset i. $X_i(t)$ is the nominal exchange rate of asset i, with respect to the base economy of the simulation. $X^{UF}(t)$ is the nominal exchange rate of the unit fund, with respect to the base economy of the simulation. $V_i(t)$ is the market value of asset i. $V^{UF}(t)$ is the total market value of the unit fund. $V_i(t) = P_i(t) \times U_i(t)$ **Note** An asset duration of 0 is applied for instruments in the SG tree that do not have a duration output.

Name	Description
Convexity	For a unit fund with N holdings, each with a convexity, $C_i(t)$. The convexity of the unit fund, $C^{UF}(t)$, at time t can be calculated as: $$C^{UF}(t) = \sum_{i=1}^{N} C_i(t) \times \frac{V_i(t)}{V^{UF}(t)} \times \frac{X^{UF}(t)}{X_i(t)}$$ $P_i(t)$ is the unit price of asset i. $U_i(t)$ is the number of units of asset i. $X_i(t)$ is the nominal exchange rate of asset i, with respect to the base economy of the simulation. $X^{UF}(t)$ is the nominal exchange rate of the unit fund, with respect to the base economy of the simulation. $V_i(t)$ is the market value of asset i. $V^{UF}(t)$ is the total market value of the unit fund. $V_i(t) = P_i(t) \times U_i(t)$ **Note** An asset convexity of 0 is applied for instruments in the SG tree that do not have a convexity output.

5 Portfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The Portfolios node is a high-level container for more complex portfolios.

Submodels

Name	Description
AssetPortfolios	Container for asset portfolios.
ManagedPortfolios	Container for managed portfolios.
AdvancedAssetPortfolios	Container for advanced asset portfolios.

5.1 AssetPortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The GenericBondPortfolios enable you to model portfolios of fixed income instruments with identical characteristics (in terms of coupon, term, and so on). In contrast, the composite portfolios described in this section let you add different types of assets to the portfolio. In addition to the features offered by the generic portfolio models, specific portfolios enable you to include individual issuers and to model their specific bond issues, cash flow schedules, and coupon frequencies.

Addable submodels

Name	Description
CompositePortfolio	A portfolio composed of a combination of bonds, cash, or equity assets.
SpecificBondPortfolio	A portfolio composed of fixed income instruments with different properties (maturity, coupon payments) issued by different credit class bond issuers.

5.1.1 CompositePortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Composite portfolios are typically used to model different asset types including equity, cash, asset parsers, and bond portfolios as one combined portfolio.

Note If an asset parser has a zero price at any time step, the proportion invested in the asset parser is shared proportionally across the other assets in the composite portfolio.

Input variables

Name	Description
Economy	The economy in which the composite portfolio is denominated.
Holdings	The composite bond portfolio holdings. The portfolio can be composed of various assets including equity, cash, asset parsers, and generic and specific bond portfolios. For each holding, fill the following values: • **AssetName**—The asset. • **Weighting**—The weighting of the asset. • **HedgeCurrency**—The economy for currency hedging. The currency hedging calculations use the nominal yield curve that you set up in Economies.Economy.NominalYieldCurves.CurrencyHedgeCurve.

Outputs

Name	Description
TotalReturn	The total return of the portfolio over the time step. Calculated using the equation: $$\mathrm{TotalReturn}(t) = \sum_{i=1}^{N} \mathrm{AssetReturn}(i) \times \mathrm{Weighting}$$ where N is the number of assets in the composite portfolio and weighting is the proportion of the asset in the portfolio. The output at time zero is meaningless and a value of 0 is given.
AnnualisedTotalReturn	The annualized total return. $$\mathrm{AnnualisedTotalReturn}(t) = \mathrm{AnnualisedIncomeReturn}(t) + \mathrm{AnnualisedCapitalChange}(t).$$
TotalReturnIndex	The total return index of the composite portfolio. Calculated using the equation: $$\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t-dt) \times (1 + \mathrm{TotalReturn}(t-dt, t))$$ where TotalReturnIndex(0) = 1.0.
RescaledTRI [StartVal]	The total return index (TRI) of this asset, rescaled to the specific starting value.

Name	Description
ExcessReturn	The return earned on the portfolio in excess of the risk free return.
ExcessReturnIndex	The excess return index of the portfolio, which the application calculates as: $$\begin{aligned}&\text{ExcessReturnIndex}(t)\\&\quad=\text{ExcessReturnIndex}(t-\Delta t)\times(1+\text{ExcessReturn}(t))\end{aligned}$$ where ExcessReturnIndex(0) = 1.
CapitalChange	The capital change of portfolio over previous time step. Calculated using the equation: $$\text{CapitalChange}(t)=\sum_{i=1}^{N}\text{AssetCapitalChange}(t)\times\text{Weighting}$$ where N is the number of assets in the composite portfolio and weighting is the proportion of the asset in the portfolio. The output at time zero is meaningless and a default value of 0 is given.
AnnualisedCapitalChange	The annualized capital change. $$\text{AnnualisedCapitalChange}(t)=(1+\text{CapitalChange}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
CapitalIndex	The capital index of the composite portfolio. Calculated using the equation: $$\text{CapitalIndex}(t)=\text{CapitalIndex}(t-dt)\times(1+\text{CapitalChange}(t-dt,t))$$ where CapitalIndex(0) = 1.0.
IncomeReturn	The income return of the composite portfolio.
AnnualisedIncomeReturn	The annualized income return. $$\text{AnnualisedIncomeReturn}(t)=(1+\text{IncomeReturn}(t))^{\frac{1}{\Delta t}}-1$$ **Note** Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
IncomeYield	The income yield of the composite portfolio. Calculated using the equation: $$\text{IncomeYield}(t)=\sum_{i=1}^{N}\text{AssetIncomeYield}(t)\times\text{Weighting}$$ where N is the number of assets in the composite portfolio and weighting is the proportion of the asset in the portfolio.
BondGrossRedemptionYield	The gross redemption yield of the bonds in the composite portfolio. This output ignores any equity-type assets. Calculated using the equation: $$\begin{aligned}&\text{BondGrossRedemptionYield}(t)\\&\quad=\sum_{i=1}^{N}\text{GrossRedemptionYield}(i)\times\text{Weighting}\end{aligned}$$ where N is the number of assets in the composite portfolio and weighting is the proportion of the asset in the portfolio.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the portfolio total return index discounted by the cash total return index for all trials, and takes the average.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Option Implied Volatility Test	Enables you to compare option prices implied by the simulation with market implied volatilities.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

Note In a multi-economy simulation, the composite portfolio can be hedged to eliminate currency risk, or unhedged. For more information, see *Currency Hedging within the ESG: Composite Portfolios*, available on the Customer Portal.

5.1.2 SpecificBondPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

In a specific bond portfolio, each instrument is specified in detail. The bonds making up the portfolio here can be any of the following types:

- Bonds
- Municipal bonds
- MBS
- Callable securities
- Danish MBS

Note There is reduced functionality when MBS, CallableSecurity, or DanishMBS assets are included in the portfolio. In particular, since these assets do not contain a credit class, all outputs from the portfolio that are related to credit class are disabled.

You must define these assets before they can be added to the specific bond portfolio.

In terms of operation, specific bond portfolios implement a buy and hold strategy until (for assets other than MBS, CallableSecurity or DanishMBS assets) an asset matures or its credit rating falls below a specified level. When the credit class does fall below this specified level it triggers a rebalancing of the credit class. Any payments made are collated as cash and this is assumed to be rolled up at the risk free short-term interest rate.

Input variables

Name	Description
Economy	Identifies the governing credit transition matrix.
LowestCreditClass	The lowest credit class allowed in this portfolio. Any instrument (that has a credit class) falling below this class is sold and the proceeds reinvested in an equivalent asset of class RebalanceCreditClass.
RebalanceCreditClass	The credit class of the instrument that is used to reinvest the proceeds from those instruments sold because they defaulted or fell below the LowestCreditClass.
HalfSpread	The transaction cost of buying or selling an instrument in this portfolio.
Bonds	The set of instruments non-cash holdings in this portfolio at the start of each trial. Each instrument in the holding is defined by its issuer, its name and the amount held. Holdings can be added to the model configuration either manually or using bulk import.
Cash	The amount of cash held in this portfolio at the start of each trial.
InitialIndexValue	The initial index value, which the software uses in the TotalReturnIndex and CapitalIndex calculations. This value can be any real positive number.

Outputs

Name	Description
TotalReturn	The total return earned on the portfolio over the time step. The output at time zero is meaningless and a default value of 0 is given.
AnnualisedTotalReturn	The annualized total return. $$\begin{aligned}&\text{AnnualisedTotalReturn}(t)\\&\quad = \text{AnnualisedIncomeReturn}(t) + \text{AnnualisedCapitalChange}(t).\end{aligned}$$
TotalReturnIndex	The total return index of the composite portfolio. Calculated using the equation: $$\begin{aligned}&\text{TotalReturnIndex}(t)\\&\quad = \text{TotalReturnIndex}(t-\Delta t) \times (1 + \text{TotalReturn}(t))\end{aligned}$$ where TotalReturnIndex(0) = InitialIndexValue.
RescaledTRI [StartVal]	The total return index (TRI) of the portfolio, rescaled to the specific starting value.
ExcessReturn	The return earned on the portfolio in excess of the risk free return.
ExcessReturnIndex	The excess return index of the portfolio, which the application calculates as: $$\begin{aligned}&\text{ExcessReturnIndex}(t)\\&\quad = \text{ExcessReturnIndex}(t-\Delta t) \times (1 + \text{ExcessReturn}(t))\end{aligned}$$ where ExcessReturnIndex(0) = 1.
TotalCashflow	The total cash flow (in millions) for this specific bond portfolio.
CapitalChange	The capital change on the specific bond portfolio. $$\text{CapitalChange}(t-dt) = \frac{\text{CapitalIndex}(t)}{\text{CapitalIndex}(t-dt)} - 1$$ The output at time zero is meaningless and a value of 0 is given.
AnnualisedCapitalChange	The annualized capital change. $$\text{AnnualisedCapitalChange}(t) = (1 + \text{CapitalChange}(t))^{\frac{1}{\Delta t}} - 1$$

Name	Description
	Note Δt in this equation can represent the time period between index values that are chosen to be output, meaning that the change is over the output time intervals, regardless of whether these correspond to the simulation time steps.
CapitalIndex	The capital index of the specific bond portfolio. This parameter is an index of bond capital changes, that is, the total return excluding income. $$\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$$ where CapitalIndex(0) = InitialIndexValue
IncomeReturn	The income return of the specific bond portfolio.
AnnualisedIncomeReturn	The annualized income return. $$\text{AnnualisedIncomeReturn}(t) = (1 + \text{IncomeReturn}(t))^{\frac{1}{\Delta t}} - 1$$
NumDefaults	The number of defaults over the previous time step.
NumUpgrades	The number of upgrades over the previous time step.
NumDowngrades	The number of downgrades over the previous time step.
NumBondsSold	The number of bonds sold from this portfolio.
AverageCreditStatus	The average credit status of the holdings in this portfolio, weighted by the market value of holdings. A value of -1 means that there are no holdings.
Duration	The duration of this portfolio based on promised cash flows. $$V_t = \sum_t tC_t(v_t)^t / \sum_t C_t(v_t)^t$$ where C_t is the sum of all future promised cash flows arising from the asset portfolio at time *t*. Note that $v_t = \frac{1}{(1+r(t))}$, where $r(t)$ is the risk free rate.
Convexity	The convexity of this portfolio based on promised cash flows. $$W_t = \sum_t t^2 C_t(v_t)^t / \sum_t C_t(v_t)^t$$ where C_t is the sum of all future promised cash flows arising from the asset portfolio at time *t*. Note that $v_t = \frac{1}{(1+r(t))}$, where $r(t)$ is the risk free rate.
GRYield	The gross redemption yield of the portfolio based on promised nominal cash flows. If the portfolio contains any index-linked bonds, then inflation expectations are used to construct nominal cash flows for these bonds.
RealYield	The real yield of the portfolio based on promised real cash flows. If the portfolio contains any index linked bonds, then inflation expectations are used to construct real cash flows for these bonds.
MVCF [Year]	The market value of cash flows for the specified year.
Cash	The cash in the portfolio.
InstrumentValue	The value of the holdings in the portfolio.
PortfolioValue	The total value of the portfolio.
Payments	The payments from the holdings in the portfolio.
PrincipalPayments	The principal payments from the holdings in the portfolio.
CreditClassCount [CreditClass]	The count of holdings with a specified credit class in the portfolio.

Analysis tests

Name	Description
Asset Martingale Test	Calculates the portfolio total return index discounted by the cash total return index for all trials and takes the average. Portfolios that contain MBS, callable security, or Danish MBS are not expected to pass martingale tests.
Local Currency Asset Martingale Test	Calculates the asset total return index discounted by the cash total return index of the economy of the asset for all trials and takes the average. The test passes only if UseRiskNeutralValuation is set to True and the correlations between the ExchangeRate.dZ risk factor of the foreign economy and all non-ExchangeRate.dZ risk factors are set to zero.
Convergence Test	Calculates the average excess return index at the last simulation time step number for trials 1 to n.

5.2 ManagedPortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The ManagedPortfolios container holds the accounting conventions, standalone managed portfolios, and managed portfolio groups for the managed portfolios functionality.

For more information about the Managed Portfolios functionality, see the *Scenario Generator Managed Portfolios Getting Started Guide*.

Submodels

Name	Description
AccountingConventions	Container for the accounting conventions that you can use, in conjunction with managed portfolios, to calculate accounting outputs.
TradingConditions	A container, in which you can define the trading conditions that you want to add to buy instructions and rules.

Addable submodels

Name	Description
StandaloneManagedPortfolio	A model that comprises initial asset holdings, a cash account, and buy and sell instructions. It is self-contained, so investment returns and sale proceeds from its asset holdings are automatically directed towards its own cash account.
ManagedPortfolioGroup	A container, to which you can add multiple managed portfolio models that have related investment objectives. The container comprises a group cash account and rules. You define the investment objectives in the group rules. The container can also contain liabilities, which are paid from the group cash account.

5.2.1 AccountingConventions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Container for accounting conventions, which you can use in the managed portfolios to calculate accounting outputs. Conventions are split by the assets to which you can apply them. You can also add property accounting conventions that require parameters that you define.

Submodels

Name	Description
BondAccountingConventions	Accounting conventions that apply specifically to bond assets.
EquityAccountingConventions	Accounting conventions that apply specifically to equity and fund assets.
PropertyAccountingConventions	Accounting conventions that apply specifically to property assets.
CommonAccountingConventions	Accounting conventions that you can apply to any type of asset, to produce accounting outputs.

BondAccountingConventions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Submodels

Name	Description
LinearAmortisation	Accounting convention that records the carrying amount, such that any difference between initial fair value and nominal value is amortized equally over the lifetime of the bond, subject to impairments.
EffectiveInterestRateAmortisation	Accounting convention where the carrying amount evolves over time in a formulaic way, according to a calculated effective interest rate, subject to impairments.
ImpairmentEvents	Events that trigger an impairment of bond carrying amounts, under linear and effective interest rate amortization methods.

LinearAmortisation

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Accounting convention that calculates the carrying amount, such that any difference between initial fair value and nominal value is amortized equally over the lifetime of the bond, subject to impairments. There is no parametrization provided for this model, because relevant details are collected from individual bond characteristics.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

EffectiveInterestRateAmortisation

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Under this accounting convention, the carrying amount of the bond evolves in a formulaic way from its initial carrying amount according to a calculated effective interest rate.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

ImpairmentEvents

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Addable submodels

Name	Description
BondImpairmentEvent	Events that trigger an impairment of bond carrying amounts, under applicable conventions.

BondImpairmentEvent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Events that trigger an impairment of bond carrying amounts. The impairment types available are CreditDowngrade and RelativeCreditDowngrade.

Credit Downgrade is applicable to credit risky bonds only, and is triggered when the credit class of the bond issuer falls below a specified credit class. For example, it may be defined that bonds should be impaired if the credit class falls below investment grade (BBB) and does not recover to least the BBB state for three consecutive months.

The initial credit rating of the issuer of the bond is stored and compared to the actual credit class in each time step. If $\mathrm{CreditRating}(t) < \mathrm{ImpairmentTriggerValue}$ for a number of consecutive time steps (defined by the impairment **Period**) up to and including the current time step t, then the impairment is recognized.

Relative Credit Downgrade is applicable to credit risky bonds only, and is triggered when the credit class of the bond issuer falls from its initial credit class by a certain number of credit classes. For example, it might be considered that an impairment event occurs when the credit class of a bond issuer falls relative to the initial credit class by two credit classes and does not recover by at least one credit class for eight consecutive months.

The initial credit rating of the issuer of the bond is stored and compared to the actual credit class in each time step. If $\text{CreditRating}(t) < \text{InitialCreditRating}$ for a number of consecutive time steps (defined by the impairment **Period**) up to and including the current time step t, then the impairment is recognized.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

Input variables

Name	Description
ImpairmentMetric	From the drop-down list, select the metric that you want to use to define impairments. • **CreditDowngrade**—A credit downgrade to the class that you specify in ImpairmentTriggerValue. • **RelativeCreditDowngrade**—A credit downgrade by the number of classes that you specify in ImpairmentTriggerValue.
ImpairmentTriggerValue	Select the impairment trigger value. If **ImpairmentMetric** is **CreditDowngrade**, this is the credit class that defines impairments. • **1**—AAA • **2**—AA • **3**—A • **4**—BBB • **5**—BB • **6**—B • **7**—CCC • **8**—Default If **ImpairmentMetric** is **RelativeCreditDowngrade**, then the impairment is triggered by a downgrade by the number of classes that you specify in this parameter.
Period	The number of consecutive time steps over which the impairment condition that you specify in **ImpairmentMetric** and **ImpairmentTriggerValue** must be satisfied before the software triggers the impairment event.

EquityAccountingConventions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Submodels

Name	Description
HistoricalCost	Accounting convention where the carrying amount is reported as the initial purchase price of the asset, subject to impairments. If an asset is impaired, the carrying amount is reported as the lowest achieved asset value and the impairment cannot be reversed.
Cost	Accounting convention where the carrying amount is reported as the initial purchase price of the asset, subject to impairments. If an asset is impaired, the carrying amount is reported as the fair value of the asset for each time step that the fair value is below the initial purchase price. When the fair value increases above the initial purchase price, any impairment is reversed and the carrying amount reverts to the initial purchase price.

HistoricalCost

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Under the historical cost accounting convention, the carrying amount is maintained at the purchase price.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

Cost

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Under the cost accounting convention, the carrying amount is maintained at the purchase price, unless the asset is impaired.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

PropertyAccountingConventions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Addable submodels

Name	Description
DecliningBalanceDepreciation	Accounting convention where the carrying amount is reduced over time by a specified depreciation rate.

Name	Description
LinearDepreciation	Accounting convention that reports the carrying amount, such that the difference between the initial carrying amount and intended disposal value is written off equally over a specified time period.

DecliningBalanceDepreciation

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Accounting convention where the carrying amount is reduced over time by a specified depreciation rate.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

Input variables

Name	Description
DepreciationRate	The annual rate at which depreciation is assumed to occur.

LinearDepreciation

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Accounting convention that reports the carrying amount, such that the difference between the initial carrying amount and intended disposal value is written off linearly over a specified time period.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

Input variables

Name	Description
IntendedDisposalFactor	Multiple of the initial fair value (or fair value at purchase) at which the property is planned to be sold, at the intended horizon.
IntendedHorizon	Length of time over which the property is planned to be held, specified in years, from the latter of time 0 or the point of purchase. The carrying amount remains at the disposal value for any asset held longer than the intended horizon.

CommonAccountingConventions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Submodels

Name	Description
FairValuePNL	Convention that calculates carrying amounts (book value) as the fair value (market value) of the asset. Under this convention, gains and losses are recognized in profit and loss.
FairValueOCI	Convention that calculates carrying amounts (book value) as the fair value (market value) of the asset. Under this convention, gains and losses are recognized in other comprehensive income.
ImpairmentEvents	Events that trigger an impairment of asset carrying amounts, under DecliningBalanceDepreciation, LinearDepreciation, HistoricalCost, LinearAmortisation, and EffectiveInterestRateAmortisation.

FairValuePNL

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Convention that calculates carrying amounts (book value) as the fair value (market value) of the asset. Under this convention, gains and losses are recognized in profit and loss.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

FairValueOCI

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Convention that calculates carrying amounts (book value) as the fair value (market value) of the asset. Under this convention, gains and losses are recognized in other comprehensive income.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

ImpairmentEvents

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Addable submodels

Name	Description
ImpairmentEvent	Event that you can apply to any asset class to trigger an impairment of the asset carrying amount.

ImpairmentEvent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Event that you can apply to any asset class to trigger an impairment of the asset carrying amounts.

Note In the following calculations, a superscript asterisk after a variable (*for example*, x^*) indicates that the metric is in the currency of the asset.

The available impairment event is RelativeValueFall. This impairment event is triggered when the fair value of the holding falls below a threshold defined to be a certain proportion of the unimpaired carrying amount. *For example*, an impairment event might be defined to occur when the fair value drops to less than 70% of the evolving carrying amount (that is, relative fall of 30%, from a defined ImpairmentTriggerValue of 0.3) and does not recover for six consecutive months (time steps).

Let $\mathrm{GrossCarryingAmount}_i^*$ be the carrying amount of holding i at time t before impairments are considered, which depends on the amortization profile. The impairment metric is the relative value fall, defined as:

$$\mathrm{ImpairmentMetric}_i = \frac{\mathrm{GrossCarryingAmount}_i^*(t) - \mathrm{FairValue}_i^*(t)}{\mathrm{GrossCarryingAmount}_i^*(t)}$$

for asset holding i.

If $\mathrm{ImpairmentMetric}_i(t) > \mathrm{ImpairmentTriggerValue}$ for a number of consecutive time steps (defined by the impairment *Period*) up to and including the current time step t, then the impairment is recognized.

For more information, see the Accounting section of the *Scenario Generator Managed Portfolios Methodology Guide*.

Input variables

Name	Description
ImpairmentMetric	The impairment metric that triggers this impairment event. • **RelativeValueFall**—A fall in relative value.
ImpairmentTriggerValue	The value of the **ImpairmentMetric** that triggers the impairment event.
Period	The number of consecutive time steps over which the impairment condition that you specify in **ImpairmentMetric** and **ImpairmentTriggerValue** must be satisfied before the software triggers the impairment event.

5.2.2 TradingConditions

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This model enables you to define trading conditions as submodels. Each trading condition can be economic or time-based, defined using one or more of the outputs available from the Simulation, Economies, and Assets nodes of the ESG tree, or the FundingRatio of a managed portfolio group. A trading condition can then be added to the buy instructions or rules in Managed Portfolios to enable you to specify the circumstances under which these rules or instructions operate.

Addable submodels

Name	Description
TradingCondition	Model defining a set of economic or time-based conditions.

TradingCondition

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A TradingCondition is a set of economic conditions. After you have set up a trading condition, you can select it in a buy instruction or rule.

Input variables

Name	Description
Conditions	Defines one or more conditions for the trading condition. For each condition, fill the following fields: • **LowerBound**—The lower bound for the model output. • **LowerBoundOperator**—The operator for the lower bound. • **ModelOutput**—The numerical output from the tree to check for the condition, from the Economy, Assets, and ESG nodes. The FundingRatio from a ManagedPortfolioGroup is also available. You cannot use other outputs from ManagedPortfolios, or any outputs from EquityAssetFactors, AdvancedAssetPortfolios, or AssetPortfolios. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the model output. • **LogicalOperator**—**AND** or **OR**. AND is evaluated before OR.

5.2.3 StandaloneManagedPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The Standalone Managed Portfolio model comprises initial asset holdings, a cash account, and buy and sell instructions. It is self-contained, so investment returns and sale proceeds from its asset holdings are automatically directed towards its own cash account.

Input variables

Name	Description	Condition
Economy	The economy of the managed portfolio.	
FairValueCalculationMethod	From the drop-down list, select the calculation method that you want to use for the fair value of any bonds in the portfolio: • **ModelledFairValue**—The fair value at the start of the projection is reported as the ESG calculated value of the bond holdings. • **FairValueDefinedScalingPeriod**—The fair value at the start of the projection is reported as the input fair value of the bond holdings. A spread is added to the bond discount rate, which the software removes over the scaling period. • **FairValueScalingPeriodByMaturity**—The fair value at the start of the projection is reported as the input fair value of the bond holdings. A spread is added to the bond discount rate, which the software removes over the lifetime of each bond.	
ScalingPeriod	The scaling period over which the software removes the spread from the bond discount rate.	Enabled only if **FairValueCalculationMethod** is **FairValueDefinedScalingPeriod**
BondImpairments	Select the bond impairment events that are valid for this portfolio. These impairments can be bond or common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The bond or common impairment event. • **LogicalOperator**—**AND** or **OR**. For the **IAS** Accounting Methodology, these events will determine when a bond should be impaired, and therefore whether an impairment provision should be calculated. For the **IFRS** Accounting Methodology, these events will determine when a bond should move between Stage 1 and Stage 2, and determines which calculation for impairment provision should be used.	
EquityImpairments	Select the equity impairment events that are valid for this portfolio. These impairments can be equity or common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The equity or common impairment event. • **LogicalOperator**—**AND** or **OR**.	
PropertyImpairments	Select the property impairment events that are valid for this portfolio. These impairments can be property, equity, or common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The property, equity, or common impairment event. • **LogicalOperator**—**AND** or **OR**.	

Name	Description	Condition
FundImpairments	Select the fund impairment events that are valid for this portfolio. These impairments can be equity or common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The equity or common impairment event. • **LogicalOperator**—**AND** or **OR**.	
AccountingMethodology	From the drop-down list, select the accounting framework that you want to use for determining how gains and impairments are calculated: • **IAS** • **IFRS**	

Submodels

Name	Description
Cash	Acts as the cash account for this portfolio.
InitialHoldings	Defines the time 0 asset holdings of the portfolio.
InvestmentStrategy	Contains the buy and sell instructions that make up the investment strategy of the portfolio.

Outputs

Name	Description
TotalFairValue	The market value of the portfolio. This value reflects the entire portfolio including all assets currently held, and any cash in the cash account. $$\text{FairValue}_p(t) = \text{Cash}_p.\text{TotalValue} + \sum_{a \in P_p} \text{FairValue}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $\text{Cash}_p.\text{TotalValue}$ is the balance of the cash account in the managed portfolio. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
TotalFairValueReturn	The total of the fair return across all assets held by the portfolio, *p*, regardless of accounting convention. $$\text{TotalFairValueReturn}_p(t) = \frac{\text{TotalFairValue}_p(t)}{\text{TotalFairValue}_p(t - \Delta t)} - 1$$ The initial fair value return is zero: $\text{TotalFairValueReturn}_p(0) = 0$.
Duration	The duration of the portfolio. Derived by weighting the duration of each instrument by its share in the fair value when converted to the currency of the managed portfolio. The duration of portfolio *p* is: $$\text{Duration}_p(t) = \frac{X_p(t)}{\text{FairValue}_p(t)} \times \sum_{a \in P_p} \frac{\text{FairValue}_a(t)}{X_a(t)} \times \text{Duration}_a(t)$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.

Name	Description
	Note Cash has duration of zero and hence contributes to FairValue *p* but not the summation in the equation above. The end result of an increasing cash balance (*for example*, to a very large value) is a reduction of the duration (that is, to a very small positive value). When we have multiple instruments from different currencies and different credit ratings the duration can be interpreted as a sensitivity to a parallel shift of all reference yield curves.
Convexity	Derived by weighting the convexity of each instrument by its share in the fair value when converted to the managed portfolio. The convexity of the portfolio, *p*, is: $$\text{Convexity}_p(t) = \frac{X_p(t)}{\text{FairValue}_p(t)} \times \sum_{a \in P_p} \frac{\text{FairValue}_a(t)}{X_a(t)} \times \text{Convexity}_a(t)$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively. **Note** Cash has convexity of zero and hence contributes to FairValue *p* but not the summation in the equation above. The end result of an increasing cash balance (*for example*, to a very large value) is a reduction of the convexity (that is, to a very small positive value).
TotalCarryingAmount	The net carrying amount of the assets, including cash, in the portfolio, regardless of accounting convention. $$\text{CarryingAmount}_p(t) = \text{Cash}_p.\text{TotalValue} + \sum_{a \in P_p} \text{CarryingAmount}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $\text{Cash}_p.\text{TotalValue}$ is the balance of the cash account in the managed portfolio. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
TotalRealisedGain	Absolute measure of gains or losses (if negative) that have been realized. Defined below, in the currency of the portfolio, for all assets sold at the time step. $$\text{TotalRealisedGain}(t) = \sum_{a \in P_p}^{sold(t-\Delta t,t)} \text{RealisedGain}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio respectively. **Note** $\text{TotalRealisedGain}(t) = \text{InvestmentStrategy.TotalGainsRealised} - \text{InvestmentStrategy.TotalLossesRealised}$ For the asset level calculation of realized gain under IAS/IFRS accounting methodology, see the *Scenario Generator Managed Portfolios Methodology Guide*.
TotalRelativeRealisedGain	Relative measure of gains or losses (if negative) that have been realized. $$\text{TotalRelativeRealisedGain}(t) = \frac{\text{TotalRealisedGain}_p(t)}{\sum_{a \in P_p}^{sold(t-\Delta t,t)} \text{CarryingAmount}_a(t) \times \frac{X_p(t)}{X_a(t)}}$$
TotalRelativeUnrealisedGain	Relative measure of gains or losses (if negative) that have not been realized. $$\text{TotalRelativeUnrealisedGain}(t) = \frac{\text{TotalUnrealisedGain}(t)}{\text{TotalCarryingAmount}(t)}$$

Name	Description
TotalUnrealisedGain	Absolute measure of gains or losses (if negative) that have not been realized. This measure reflects the amount that would have been realized if the assets had been sold at the particular time step. Defined below, in the currency of the portfolio, for all assets held within the portfolio at the end of the time step (including cash). $$\text{TotalUnrealisedGain}(t) = \sum_{a \in P_p}^{sold(t-\Delta t,t)} \text{UnrealisedGain}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio respectively. For the asset level calculation of unrealized gain under IAS/IFRS accounting methodology, see the *Scenario Generator Managed Portfolios Methodology Guide*.
TotalOrdinaryIncome	Investment income received in the form of coupons, dividends, or rental income (dependent on asset type). This value includes the return on any cash invested in the cash account, plus the scheduled change in carrying amount for assets classified under specified accounting conventions, in the currency of the portfolio. For MBS, it also includes the scheduled PrincipalPayments. **Note** When bonds mature, the nominal value is collected as cash, and this is not recognized as ordinary income. $$\text{TotalOrdinaryIncome}(t) = \sum_{a \in P_p} \text{OrdinaryIncome}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • For assets classified as FairValuePNL, FairValueOCI, and HistoricalCost, $$\text{OrdinaryIncome}_a(t) = \text{InvestmentIncome}_a(t)$$ • For assets classified as EffectiveInterestRateAmortisation, LinearAmortisation, DecliningBalanceDepreciation, LinearDepreciation, $$\begin{aligned}&\text{OrdinaryIncome}_a(t)\\ &\quad = \text{InvestmentIncome}_a(t) + \text{CarryingAmount}_a(t)\\ &\quad - \text{CarryingAmount}_a(t - \Delta t)\end{aligned}$$ • For MBS assets, $$\begin{aligned}&\text{OrdinaryIncome}_a(t)\\ &\quad = \text{InvestmentIncome}_a(t) + \text{PrincipalPayments}_a(t)\end{aligned}$$ • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
TotalEarnings	The earnings value at each time step, reported in the currency of the portfolio. $$\begin{aligned}\text{TotalEarnings}(t) &= \text{TotalOrdinaryIncome}(t) - \text{TotalDefaultLoss}(t) - \text{TotalImpairmentLoss}(t)\\ &+ \text{TotalRealisedGain}(t) + \text{CurrencyHedgeIncome}(t)\\ &+ \sum_{FairValuePNLa \in P_p} \left(\text{CarryingAmount}_a(t) - \text{CarryingAmount}_a(t - dt)\right) \times \frac{X_p(t)}{X_a(t)}\end{aligned}$$ When using asymmetric output settings, this output will equal the sum of the TotalEarnings (calculated using the equation above) at each of the intermediate timesteps.

Name	Description
TotalBookReturn	The total of the book return across all assets held by the portfolio, *p*, regardless of accounting convention. $$\mathrm{TotalBookReturn}_p(t) = \frac{\mathrm{TotalCarryingAmount}_p(t)}{\mathrm{TotalCarryingAmount}_p(t-\Delta t)} - 1$$ The initial book return is zero: $$\mathrm{TotalBookReturn}_p(0) = 0$$
TotalImpairmentProvision	The total impairment provision at each time step, reported in the currency of the portfolio. $$\mathrm{ImpairmentProvision}(t) = \sum_{a \in P_p} \mathrm{ImpairmentProvision}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively. For the asset level calculation of impairment provision under IAS/IFRS accounting methodology, see the *Scenario Generator Managed Portfolios Methodology Guide*.
TotalImpairmentLoss	The change in impairment provision for all the assets within the portfolio that are subject to impairment, reported in the currency of the portfolio.
TotalCurrencyTranslationGain	Absolute measure of gains or losses (if negative) that have occurred due to exchange rate movements at each time step, for all assets within the portfolio (including cash invested in the cash account). This output is reported in the currency of the portfolio.
TotalDefaultLoss	The loss incurred when bonds in the portfolio have defaulted over the time step. This output is reported in the currency of the portfolio.
FairValue [AccountingConvention]	The aggregate fair value of all the assets within the portfolio that are classified under the specified accounting convention (excludes cash in the cash account). This output is reported in the currency of the portfolio.
CarryingAmount [AccountingConvention]	The aggregate book value of all the assets within the portfolio that are classified under the specified accounting convention (excludes cash in the cash account). This output is reported in the currency of the portfolio.
RealisedGain [AccountingConvention]	Absolute measure of gains or losses (if negative) that have been realized at each time step, through sales of portfolio assets that are classified under the specified accounting convention. This output is reported in the currency of the portfolio.
RelativeRealisedGain [AccountingConvention]	Relative measure of gains or losses (if negative) that have been realized at each time step, through sales of portfolio assets that are classified under the specified accounting convention.
RelativeUnrealisedGain [AccountingConvention]	Relative measure of gains or losses (if negative) that have not yet been realized at each time step, for assets within the portfolio that are classified under the specified accounting convention.
UnrealisedGain [AccountingConvention]	Absolute measure of gains or losses (if negative) that have not yet been realized at each time step, for assets within the portfolio that are classified under the specified accounting convention. This output is reported in the currency of the portfolio.
OrdinaryIncome [AccountingConvention]	Investment income plus scheduled changes in carrying amount, for all assets within the portfolio that are classified under the specified accounting convention (excludes cash invested in the cash account). For MBS, it also includes the scheduled PrincipalPayments. This output is reported in the currency of the portfolio.
ImpairmentProvision [AccountingConvention]	The impairment provision, for all assets within the portfolio that are classified under the specified accounting convention and are subject to impairment, at each time step. This output is reported in the currency of the portfolio.

Name	Description
ImpairmentLoss [AccountingConvention]	The change in impairment provision for all the assets within the portfolio that are subject to impairment and classified under the specified accounting convention. This output is reported in the currency of the portfolio.
DefaultLoss [AccountingConvention]	The loss incurred when bonds in the portfolio, classified under the specified accounting convention, have defaulted over the time step. This output is reported in the currency of the portfolio.
Vega	Measure of the change in value of the equity options due to a change in the implied volatility of the underlying equity. The vega of call/put option *i* is given by $$\mathrm{Vega}_i(t) = \mathrm{EquityAsset.TotalReturnIndex}_i^*(t) \times N_i'(d_1) \times \sqrt{\mathrm{Maturity} - t}$$ where $N'(\cdot)$ is the density of standard normal distribution. Vega is negative when selling calls and puts. The vega of the portfolio is given by $$\mathrm{Vega}(t) = \sum_i \mathrm{Vega}_i(t) \times \mathrm{NumberOfOptions}_i(t)$$
Delta	Measure of the change in value of the equity options due to a change in the value of the underlying equity. The delta of call/put option *i* is given by $$\mathrm{Delta}_i(t)_{CALL} = e^{-\ln(1+EquityAsset.DividendYield(t))\times(T-t)} \times N_i(d1)$$ $$\mathrm{Delta}_i(t)_{PUT} = -e^{-\ln(1+EquityAsset.DividendYield(t))\times(T-t)} \times N_i(-d1)$$ The delta of the portfolio is given by $$\mathrm{Delta}(t) = \sum_i \mathrm{Delta}_i(t) \times \mathrm{NumberOfOptions}_i(t)$$

Cash

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The cash account keeps track of the cash that is held within the managed portfolio. In general terms, the cash balance increases when cash is received from assets held in the portfolio (interest payments, dividends, rental income, maturities, and recovery from default) and also when assets are sold. Conversely, the cash balance decreases when cash is used to buy assets, but the net amount in the cash account cannot go negative.

Any cash left in the cash account after application of the buy instructions at any time step is rolled up at the risk-free rate of the portfolio economy to the next time step.

Input variables

Name	Description
InitialCash	The amount of cash held in the portfolio at the start of the simulation, in the currency of the portfolio.

Outputs

Name	Description
TotalValue	The total value of cash in this portfolio, in the currency of the portfolio. $$\begin{aligned}\mathrm{TotalValue}(t) = \mathrm{TotalValue}(t-\Delta t) + \mathrm{CashReturnInflow}(t) + \mathrm{InvestmentInterest}(t) \\ + \mathrm{PrincipalPayments}(t) + \mathrm{PrepaymentIncome}(t) + \mathrm{RefinancingIncome}(t) \\ + \mathrm{CurrencyHedgeIncome}(t) + \mathrm{DefaultRecoveryPayments}(t) + \mathrm{InvestmentStrategyNetInflow}(t)\end{aligned}$$
CashReturnInflow	The interest received on the cash held in the portfolio over the last time step, assuming that the cash is rolled up at the risk-free rate. $$\begin{aligned}&\mathrm{CashReturnInflow}(t) \\ &\quad = \mathrm{TotalValue}(t-\Delta t) \times (\exp(\mathrm{ShortRate}(t-\Delta t) \times \Delta t) - 1)\end{aligned}$$ where ShortRate is the short rate output of the nominal yield curve of the economy of the managed portfolio.
InvestmentIncome	Regular income from the assets held in the portfolio, including coupons, dividends, rental income, and so on, reported in the currency of the portfolio. MBS investment income is the interest part of the scheduled mortgage repayments installments received within the time step. $$\mathrm{InvestmentIncome}(t) = \sum_{a \in P_p} C_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $C_a(t)$ is the income cash flow (that is, coupon, dividend, or rental income) received from an asset over the time step. • The summation is over all assets, *a*, held in the portfolio, *p*. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
PrincipalPayments	Cash inflow from return of principal when bonds mature, in the currency of the portfolio. The principal payments from any MBS holdings are the principal part of the scheduled mortgage repayment installments received within the time step. $$\mathrm{PrincipalPayments}(t) = \sum_{a \in P_p} P_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $P_a(t)$ is the return of principal payment received from an asset over the time step. • The summation is over all assets, *a*, held in the portfolio, *p*. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
PrepaymentIncome	Cash income from MBS prepayment, in the currency of the portfolio. $$\begin{aligned}\mathrm{PrepaymentIncome}(t) = \sum_i \mathrm{UnitBalance}_i \times \mathrm{UnitsHeld}_i(t) \\ \times \mathrm{Prepayment}_i(t) \times \frac{X_p(t)}{X_a(t)}\end{aligned}$$ where $\mathrm{Prepayment}_i(t)$ is the deterministic cash flow, based on the PSA prepayment schedule, for each MBS holding *i* within the portfolio.

Name	Description
RefinancingIncome	Cash income from MBS refinancing, in the currency of the portfolio. $$\mathrm{RefinancingIncome}(t) = \sum_i \mathrm{UnitBalance}_i \times \mathrm{UnitsHeld}_i(t) \times \mathrm{RefinancingCashflow}_i(t) \times \frac{X_p(t)}{X_a(t)}$$ where $\mathrm{RefinancingCashflow}_i(t)$ is the stochastic refinancing cash flow for each MBS holding *i* within the portfolio.
CurrencyHedgeIncome	Cash income received from the maturity of the currency forward contracts underlying currency hedged assets within the portfolio, in the currency of the portfolio. For more information about the calculation of this output, see the CurrencyHedging section of the *Scenario Generator Managed Portfolios Methodology Guide*.
DefaultRecoveryPayments	Cash recovered after the default of bonds, in the currency of the portfolio. $$\mathrm{DefaultRecoveryPayments}(t) = \sum_{a \in P_p} R_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $R_a(t)$ is any recovery from the default of an asset over the time step. • The summation is over all assets, *a*, held in the portfolio, *p*. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
InvestmentStrategyNetInflow	Net cash received from all buy and sell instructions, including: • Positive amounts from the sale of instruments • Negative amounts from the purchase of instruments
GroupRulesInflow	This output is not applicable for standalone managed portfolios, and simply returns 0.

InitialHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and respective accounting conventions for the assets in the managed portfolio.

Addable submodels

Name	Description
FixedCouponSpecificBondHoldings	Defines the time zero holdings and accounting convention for specific issuer bonds in the managed portfolio.
FixedCouponGenericBondHoldings	Defines the time zero holdings and accounting convention for generic issuer bonds in the managed portfolio.
EquityHoldings	Defines the time zero holdings and accounting convention for equity assets in the managed portfolio.
FundHoldings	Defines the time zero holdings and accounting convention for funds in the managed portfolio.

Name	Description
PropertyHoldings	Defines the time zero holdings and accounting convention for property assets in the managed portfolio.
EquityOptionHoldings	Defines the time zero holdings for equity options in the managed portfolio.
MBSHoldings	Defines the time zero holdings for mortgage-backed securities in the managed portfolio.

FixedCouponSpecificBondHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for specific issuer bonds in the managed portfolio.

Input variables

Name	Description
FixedCouponSpecificBondHoldings	Define the specific bond holdings at time zero. For each holding, fill the following fields: • **Name**—The name of the holding. • **Issuer**—The specific issuer for the bond. For more information about SpecificIssuers, see SpecificIssuers. • **Economy**—Defines the currency in which the bonds are issued, which can be different from the economy of the issuer. This value defines the yield curve that the software uses for discounting payments. • **NumberOfBonds**—The number of bonds held. • **TotalNominalValue**—The total nominal value, for all bonds. *For example*, if TotalNominalValue is 500 and NumberOfBonds is 5, then the nominal value per bond is 100. • **TotalInitialFairValue**—The total initial fair value, for all bonds, in the currency of the bond assets. • **TotalInitialCarryingAmount**—The total initial carrying amount, for all bonds, in the currency of the bond assets. • **Type**—**Nominal** or **IndexLinked**. • **Term**—The term to maturity of the bonds. • **Coupon**—The annual coupon rate of the bonds. • **Frequency**—The number of coupon payments per year. • **Seniority**—The seniority of the bonds. • **AccountingConvention**—The accounting convention for the bonds. For more information about accounting conventions, see AccountingConventions • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged.

FixedCouponGenericBondHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for generic issuer bonds in the managed portfolio.

Input variables

Name	Description
FixedCouponGenericBondHoldings	Define the generic bond holdings at time zero. For each holding, fill the following fields: • **NumberOfIssuers**—The number of issuers for this holding. • **CreditClass**—The credit class for this holding. • **CreditModel**—The credit model for this holding. • **EquityAsset**—The equity asset for this holding. **Note** CreditClass, CreditModel, and EquityAsset define the bond issuers. • **Economy**—The currency in which the bonds are issued, which can be different from the economy of the issuer. This value defines the yield curve that the software uses for discounting payments. • **TotalNumberOfBonds**—The total number of bonds, which must be an integer multiple of NumberOfIssuers. Each issuer issues a number of bonds equal to TotalNumberOfBonds/ NumberOfIssuers. • **TotalNominalValue**—The total nominal value, for all bonds. *For example*, if TotalNominalValue is 500 and TotalNumberOfBonds is 5, then the nominal value per bond is 100. • **TotalInitialFairValue**—The total initial fair value, for all bonds, in the currency of the bond assets. • **TotalInitialCarryingAmount**—The total initial carrying amount, for all bonds, in the currency of the bond assets. • **Type**— **Nominal** or **IndexLinked**. • **Term**—The term to maturity of the bonds. • **Coupon**—The annual coupon rate of the bonds. • **Frequency**—The number of coupon payments per year. • **Seniority**—The seniority of the bonds. • **AccountingConvention**—The accounting convention for the bonds. For more information about accounting conventions, see AccountingConventions • **AlreadyImpaired**—Select whether this holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from this holding are currency hedged.

EquityHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for equities in the managed portfolio.

Input variables

Name	Description
EquityHoldings	Define the equity holdings at time zero. For each holding, fill the following fields: • **EquityAsset**—The equity asset for the holding. • **TotalInitialFairValue**—The initial fair value for the holding, in the currency of the asset. • **TotalInitialCarryingAmount**—The total initial carrying amount for the holding, in the currency of the asset. • **AccountingConvention**—The accounting convention for the equity holding. For more information about accounting conventions, see AccountingConventions. • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged.

FundHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for funds in the managed portfolio.

Input variables

Name	Description
FundHoldings	Define the fund holdings at time zero. For each holding, fill the following fields: • **FundAsset**—The fund asset for this holding. • **TotalInitialFairValue**—The initial fair value for this holding, in the currency of the asset. • **TotalInitialCarryingAmount**—The total initial carrying amount for this holding, in the currency of the asset. • **AccountingConvention**—The accounting convention for the fund holding. For more information about accounting conventions, see AccountingConventions. • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02.

PropertyHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for property assets in the managed portfolio.

Input variables

Name	Description
PropertyHoldings	Define the property holdings at time zero. For each holding, fill the following fields: • **PropertyAsset**—The property asset for the holding. Property assets are defined under ESG.Assets.EquityAssets. • **NumberOfUnits**—The number of units that make up the holding. • **TotalInitialFairValue**—The initial fair value for the holding, in the currency of the asset. • **TotalInitialCarryingAmount**—The total initial carrying amount for the holding, in the currency of the asset. • **AccountingConvention**—The accounting convention for the property holding. For more information about accounting conventions, see AccountingConventions. • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SmoothingMeanAge**—The intended mean age (in years) of the data weightings for the smoothing functionality. This value must be greater than or equal to zero. A value of zero indicates no smoothing. • **SaleCost** —The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge** —Select whether the returns from the holding are currency hedged. **Note** Property holdings are sold in units, and the fair value of a unit at time zero is defined as $\mathrm{TotalInitialFairValue}/\mathrm{NumberOfUnits}$

EquityOptionHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the equity options held at time zero.

Input variables

Name	Description
EquityOptionHoldings	Define the equity option holdings at time zero. For each holding, fill the following fields: • **OptionType**—**Call** or **Put**. • **Position**—**Long** or **Short**. • **UnderlyingImpliedVolModel**—From the drop-down list, select a RWOptionImpliedVolatility model that you have set up. For more information, see RWOptionImpliedVolatility. • **Maturity**—Term to maturity of the option in years. • **Strike**—Strike price of the option as a proportion of the time 0 equity asset index, where the asset is defined by **UnderlyingImpliedVolModel**. • **TotalNotional**—Time 0 notional value of the option contracts.

Name	Description
	• **Settlement**—**Cash** or **Physical**. Determines whether the position is settled at maturity through the exchange of physical equity or cash. If you set this parameter to Physical and settlement involves selling an underlying equity asset that does not exist within the portfolio, the system will revert to cash settlement. • **Coverage**—If an option rolling strategy is set up under InvestmentStrategy, enter the value to use to scale the equity/cash value at maturity to determine the new notional for this option position.

MBSHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings for mortgage-backed securities in the managed portfolio. MBS holdings pay out cash flows (interest, principal, prepayment, and refinancing) as they occur with the same frequency as the time step of the simulation.

Input variables

Name	Description
MBSHoldings	Define the mortgage-backed security holdings at time zero. For each holding, fill the following fields: • **Issuer**—The MBS issuer for the holding. For more information about configuring mortgage-backed securities, see MBSIssuer. • **MtgeTerm**—The term of the mortgages in the underlying mortgage pool. • **MtgeCoupon**—The weighted average coupon of the mortgages in the pool. This value is equivalent to a weighted average of the fixed rates paid by the mortgage holders. The payments for the mortgages are monthly. • **Age**—The weighted average age, in months, of the mortgages at the start of the simulation. • **SurvivalFactor**—The survival factor. • **MBSCoupon**—The MBS coupon. • **OASMtge**—The option adjusted spread of the mortgages in the mortgage-backed security. • **NumberOfUnits**—The number of units that make up the holding. • **MBSBalanceAtIssue**—The balance of the mortgages underlying the MBS holding at its date of issue, in the currency of the asset. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged.

InvestmentStrategy

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the buy and sell instructions that make up the investment strategy.

Addable submodels

Name	Description
BondSellInstruction	Defines the characteristics of bond assets that must be sold at any time step as the projection progresses.
BondBuyInstruction	Defines which bond assets to buy as the projection progresses.
EquitySellInstruction	Defines the characteristics of equity assets that must be sold at any time step as the projection progresses.
EquityBuyInstruction	Defines which equity assets to buy as the projection progresses.
FundSellInstruction	Defines the characteristics of fund assets that must be sold at any time step as the projection progresses.
FundBuyInstruction	Defines which fund assets to buy as the projection progresses.
PropertySellInstruction	Defines the characteristics of property assets that must be sold at any time step as the projection progresses.
PropertyBuyInstruction	Defines which property assets to buy as the projection progresses.
OptionRollingInstruction	Defines how equity option contracts should be rolled at maturity.
MBSSellInstruction	Defines the characteristics of MBS assets that must be sold at any time step as the projection progresses.
MBSBuyInstruction	Defines which MBS assets to buy as the projection progresses.

Outputs

Name	Description
TotalValueBought	Aggregate of the ValueBought outputs from the individual buy instructions in the InvestmentStrategy submodels.
TotalValueSold	Aggregate of the ValueSold outputs from the individual sell instructions in the InvestmentStrategy submodels.
TotalGainsRealised	Absolute measure of gains realized at each time step, through sales of portfolio assets. Reported in the currency of the managed portfolio.
TotalLossesRealised	Absolute measure of losses realized at each time step, through sales of portfolio assets. Reported in the currency of the managed portfolio.
InvestmentStrategyNetInflow	TotalValueSold - TotalValueBought.
TotalTransactionCosts	The aggregate amount paid out in transaction costs, over the time step, in the currency of the portfolio. $$\mathrm{TotalTransactionCosts}_p(t) = \sum_j \mathrm{TransactionCosts}_j(t)$$ where the summation is over all of the buy, sell, and on demand sell instructions within the portfolio.
TotalPurchaseCosts	The aggregate amount paid out in costs for assets purchased, over the time step, in the currency of the portfolio.
TotalSaleCosts	The aggregate amount paid out in costs for assets sold, over the time step, in the currency of the portfolio.

BondSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A bond sell instruction defines the characteristics of bonds that must be sold at each time step. In a single bond sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of bonds, set up multiple BondSellInstructions. In other words, for a logical AND, use a single bond sell instruction with multiple conditions. For a logical OR, use multiple bond sell instructions.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of bonds. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. Select **Term**, **CreditClassIndex**, **Duration**, **Convexity**, **FairValueRedemptionYield**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic. If you use the **CreditClassIndex** characteristic, the mappings to credit classes are as follows: • **0**—Govt • **1**—AAA • **2**—AA • **3**—A • **4**—BBB • **5**—BB • **6**—B • **7**—CCC • **8**—Default

Outputs

Name	Description
BondsSold	The number of bonds sold over the time step.
ValueSold	The value of the bonds sold over the time step, in the currency of the managed portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.

Name	Description
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

BondBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A bond buy instruction defines which assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Defines a buy instruction. For each issuer, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the bond. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **NominalValue**—The nominal value of the bonds. • **CreditClass**—The credit class of the bonds to purchase. Characterizes the bond issuers, along with **CreditModel** and **EquityAsset**. • **CreditModel**—Select one of the existing credit models. Characterizes the bond issuers, along with **CreditClass** and **EquityAsset**. The CreditModel defines the economy of the issuer. • **EquityAsset**—Select an existing ParentEquityAsset or ParentEquityAssetCorrelationModel. Characterizes the bond issuers, along with **CreditClass** and **CreditModel**. • **Economy**—Defines the currency in which the bonds are issued, which can be different from the economy of the issuer. • **Type**—The type of bond. Select **Nominal** or **IndexLinked**. • **Term**—The term to maturity of the bonds. • **CouponDefinition**—Select **Fixed** or **Par**. • **Coupon**—The annual coupon rate of the bonds. • **Frequency**—The number of coupon payments per year. • **Seniority**—The seniority of the bonds. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02.	

Name	Description	Conditions
	• **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the purchased assets are currency hedged.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
BondsBought	Number of bonds bought, using this buy instruction, over this time step. $$\text{AssetsBought}_i(t) = \left\lfloor \frac{\text{AmountToInvest}_i}{\text{AssetPrice}_i^*(t) \times (1 + \text{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to x.
ValueBought	Value of bonds bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsBought}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

EquitySellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An equity sell instruction defines the characteristics of equity assets that must be sold at each time step. In a single equity sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of equities, set up multiple EquitySellInstructions.

In other words, for a logical AND, use a single equity sell instruction with multiple conditions. For a logical OR, use multiple equity sell instructions.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of equities. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **DividendYield**, **CapitalChange**, **CapitalIndex**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
SharesSold	Number of shares sold, using this sell instruction, over this time step.
ValueSold	Value of the shares sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

EquityBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An equity buy instruction defines which equity assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Defines the equity assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the equity asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **EquityAsset**—The equity asset purchased. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the purchased assets are currency hedged.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
SharesBought	Number of shares bought, using this buy instruction, over this time step. $\text{AssetsBought}_i(t) = \left\lfloor \frac{\text{AmountToInvest}_i}{\text{AssetPrice}_i^*(t) \times (1 + \text{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to *x*.
ValueBought	Value of the shares bought, using this buy instruction, over this time step, in the currency of the portfolio.

Name	Description
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsBought}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

FundSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A fund sell instruction defines the characteristics of fund assets that must be sold at each time step.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of funds. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **Price**, **TotalReturn**, **ReleativeUnrealisedGain** or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.

Name	Description
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

FundBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A fund buy instruction defines which fund assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Defines the fund assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the fund asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **FundAsset**—The fund asset purchased. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
UnitsBought	Number of units bought, using this buy instruction, over this time step. $$\text{AssetsBought}_i(t) = \left\lfloor \frac{\text{AmountToInvest}_i}{\text{AssetPrice}_i^*(t) \times (1 + \text{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to x.
ValueBought	Value of the units bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsBought}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

PropertySellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A property sell instruction defines the characteristics of property assets that must be sold at each time step.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of property assets. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **EarningsYield**, **CapitalIndex**, **CapitalChange**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\mathrm{TransactionCosts}(t) = \mathrm{AssetsSold}_i(t) \times \mathrm{AssetPrice}_i^*(t) \times \mathrm{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

PropertyBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A property buy instruction defines which property assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Define the property assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **PropertyAsset**—The property asset purchased. • **UnitSize**—Defines the time zero purchase price of a single unit of this asset, in the currency of the asset. This value increases in line with the property index as the projection progresses. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SmoothingMeanAge**—The intended mean age (in years) of the data weightings for the smoothing functionality. This value must be greater than or equal to zero. A value of zero indicates no smoothing. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02.	

Name	Description	Conditions
	• **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge** —Select whether the returns from the purchased assets are currency hedged.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
UnitsBought	Number of units bought, using this buy instruction, over this time step. $\mathrm{AssetsBought}_i(t) = \left\lfloor \frac{\mathrm{AmountToInvest}_i}{\mathrm{AssetPrice}_i^*(t) \times (1 + \mathrm{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to *x*.
ValueBought	Value of the units bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\mathrm{TransactionCosts}(t) = \mathrm{AssetsBought}_i(t) \times \mathrm{AssetPrice}_i^*(t) \times \mathrm{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

OptionRollingInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Option Rolling Instruction

Input variables

Name	Description
Reference	Select the reference value for the notional of option positions that are rolled. This may be **PhysicalEquity** holdings or the **Cash** value of the portfolio.

MBSSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An MBS sell instruction defines the characteristics of mortgage-backed securities that must be sold at each time step. In a single MBS sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of MBS, set up multiple MBSSellInstructions. In other words, for a logical AND, use a single MBS sell instruction with multiple conditions. For a logical OR, use multiple MBS sell instructions.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of mortgage-backed securities. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. Select one of the following options: ◦ **PricePerUnitBalance**—The Value/Balance ratio. ◦ **MtgeTerm**—The remaining term. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.

Name	Description
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

MBSBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An MBS buy instruction defines which mortgage-backed security assets to buy as the projection progresses. MBS holdings pay out cash flows (interest, principal, prepayment, and refinancing) as they occur with the same frequency as the time step of the simulation.

Input variables

Name	Description	Conditions
BuyInstruction	Defines the mortgage-backed security assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the MBS asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **UnitBalance**—The balance of the underlying mortgages per unit bought, in the currency of the asset. • **Issuer**—The issuer of the MBS asset purchased. • **MtgeTerm**—The remaining term of the mortgages in the underlying mortgage pool. • **Age**—The weighted average age, in months, of the mortgages at the time that the buy instruction executes. • **OASMtge**—The option adjusted spread of the mortgages. • **CouponDefinition**—The coupon type of the MBS assets. Select from the following options: ◦ **Fixed**—Purchase MBS assets with fixed coupons. ◦ **PrevailingRate**—Purchase MBS assets with fixed coupons implied by the prevailing rate at the time of buying, plus any spread. • **MtgeCoupon**—If **CouponDefinition** is **Fixed**, the bought MBS asset is initialized with the value in **MtgeCoupon**. If **CouponDefinition** is **PrevailingRate**, **MtgeCoupon** is the spread, in basis points, above the prevailing risk-free rate. • **MBSCoupon**—If **CouponDefinition** is **Fixed**, the bought MBS asset is initialized with the value in **MBSCoupon**. If **CouponDefinition** is **PrevailingRate**, **MBSCoupon** is the spread, in basis points, above the prevailing risk-free rate. • **PrevailingSpotRateTerm**—The term used to infer the prevailing risk-free spot rate.	

Name	Description	Conditions
	• **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the purchased assets are currency hedged.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
UnitsBought	Number of MBS assets bought, using this buy instruction, over this time step, in the currency of the portfolio. $$\text{AssetsBought}_i(t) = \left\lfloor \frac{\text{AmountToInvest}_i}{\text{AssetPrice}_i^*(t) \times (1 + \text{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$$ where: • $\text{AssetPrice}_i^*(t) = \text{UnitBalance}_i \times \text{MBSValue}_i^*(t)$. • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to *x*. Any surplus amount is added to the cash account.
ValueBought	Value of the MBS assets bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsBought}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

5.2.4 ManagedPortfolioGroup

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A container, to which you can add managed portfolios that have related investment objectives. You define the investment objectives in the group rules. A managed portfolio group can also contain liabilities, which are paid from the group cash account.

Submodels

Name	Description
Cash	This model acts as the cash account for cash flows for this portfolio group.
Rules	Models that define the investment objective of the group, and act on multiple portfolios.

Addable submodels

Name	Description
ManagedPortfolio	The Managed Portfolio model comprises initial asset holdings, a cash account, buy, sell, and on demand sell instructions that define how the assets in this portfolio are managed over time.
Liabilities	Models the liability cash flows for the managed portfolio group.
RegulatoryCapital	Contains models for the calculation of regulatory capital for the managed portfolio group.
Overlay	Contains swap models that can be used to enact hedging strategies for the managed portfolio group.

Input variables

Name	Description
Economy	The economy for the managed portfolio group.
AccountingMethodology	From the drop-down list, select the accounting framework that you want to use for determining how gains and impairments are calculated: • **IAS** • **IFRS**

Outputs

Name	Description
NetGroupValue	The net value of the group. Defined as TotalFairValue - TotalLiabilityValue, in the currency of the group.
TotalFairValue	The aggregate market value of all the assets within the group (including cash invested in cash accounts). This output is reported in the currency of the group.

Name	Description
TotalFairValueReturn	The fair value return over each time step, for all assets within the group. $$\text{TotalFairValueReturn}(t) = \frac{\text{TotalFairValue}_g(t) + \text{Cash. LiabilityCashFlow}(t)}{\text{TotalFairValue}_g(t-\Delta t)} - 1$$ To fairly reflect the performance of the group, we add back in any liability payments made in the time step, and the denominator is the total fair value in the group at the beginning of the time step. Initial fair value return is set to zero: $\text{TotalFairValueReturn}_g(0) = 0$.
TotalCashValue	The total amount held in all cash accounts within the group, denominated in the currency of the group. $$\text{TotalCashValue}(t) = \text{ManagedPortfolioGroup.Cash.TotalValue}(t) + \sum_{p \in G_g} \text{ManagedPortfolio}_p\text{.Cash.TotalValue}(t) \times \frac{X_g(t)}{X_p(t)}$$ where: X_G is the exchange rate nominal value of the economy of the group. X_P is the exchange rate nominal value of the economy of the portfolio.
FundingRatio	The funding ratio of the group. $$\text{FundingRatio(t)} = \frac{\text{TotalFairValue}_g(t)}{\text{TotalLiabilityValue}_g(t)}$$
TotalCarryingAmount	The aggregate net book value of all the assets within the group (including cash invested in cash accounts). This output is reported in the currency of the group.
TotalLiabilityValue	The fair value of all liabilities in the group, in the currency of the group.
TotalRealisedGain	Absolute measure of gains or losses (if negative) that have been realized. Defined as the sum of the realized gains, at the end of each time step, across each portfolio in the group, in the currency of the group. $$\text{TotalRealisedGain}(t) = \sum_{p \in G_g} \text{TotalRealisedGain}_p(t) \times \frac{X_g(t)}{X_p(t)}$$ where X_a and X_g are the nominal exchange rates, with respect to the base economy, of the economy of the portfolio and the economy of the group respectively. **Note** $\text{TotalRealisedGain}(t) = \text{TotalGainsRealised}(t) - \text{TotalLossesRealised}(t)$
TotalGainsRealised	Absolute measure of gains realized at each time step, through sales of group assets. Reported in the currency of the group.
TotalLossesRealised	Absolute measure of losses realized at each time step, through sales of group assets. Reported in the currency of the group.
TotalRelativeRealisedGain	Relative measure of gains or losses (if negative) that have been realized at each time step, through sales of group assets, measured in the currency of the group. $$\text{TotalRelativeRealisedGain}(t) = \frac{\text{TotalRealisedGain}_g(t)}{\sum_{a \in G_g}^{sold(t-\Delta t, t)} \text{CarryingAmount}_a(t) \times \frac{X_g(t)}{X_a(t)}}$$

Name	Description
TotalRelativeUnrealisedGain	Relative measure of gains or losses (if negative) that have not yet been realized at each time step, measured in the currency of the group. $$\text{TotalRelativeUnrealisedGain}(t) = \frac{\text{TotalUnrealisedGain}_g(t)}{\text{TotalCarryingAmount}_g(t)}$$
TotalUnrealisedGain	Absolute measure of gains or losses (if negative) that have not been realized. Defined as the sum of the unrealized gains, at the end of each time step, across each portfolio in the group, in the currency of the group. $$\text{TotalUnrealisedGain}(t) = \sum_{p \in G_g} \text{TotalUnrealisedGain}_p(t) \times \frac{X_g(t)}{X_p(t)}$$ where X_p and X_g are the nominal exchange rates, with respect to the base economy, of the economy of the portfolio and the economy of the group, respectively. **Note** $$\begin{aligned}&\text{TotalUnrealisedGain}(t)\\&\quad = \text{TotalGainsUnrealised}(t) - \text{TotalLossesUnrealised}(t)\end{aligned}$$
TotalGainsUnrealised	Absolute measure of gains that have not been realized at the time step, reported in the currency of the group. This output is the sum of TotalGainsUnrealised across portfolios in the group, adjusted for currency changes.
TotalLossesUnrealised	Absolute measure of losses that have not been realized at the time step, reported in the currency of the group. This output is the sum of TotalLossesUnrealised across portfolios in the group, adjusted for currency changes.
TotalOrdinaryIncome	Investment income (including the return on any cash invested in cash accounts) plus scheduled changes in carrying amount, for all assets within the group. For MBS, it also includes the scheduled PrincipalPayments. This output is reported in the currency of the group.
TotalEarnings	The earnings value at each time step, reported in the currency of the group. $$\begin{aligned}\text{TotalEarnings}(t) = {} & \text{TotalOrdinaryIncome}(t) - \text{TotalDefaultLoss}(t) - \text{TotalImpairmentLoss}(t)\\ & + \text{TotalRealisedGain}(t) + \text{CurrencyHedgeIncome}(t)\\ & + \sum_{FairValuePNLa \in G_g} \left(\text{CarryingAmount}_a(t) - \text{CarryingAmount}_a(t-dt)\right) \times \frac{X_g(t)}{X_a(t)}\end{aligned}$$ When using asymmetric output settings, this output will equal the sum of the TotalEarnings (calculated using the equation above) at each of the intermediate timesteps.
TotalBookReturn	Book return over each time step, for all assets within the group. $$\begin{aligned}&\text{TotalBookReturn}_g(t)\\&\quad = \frac{\text{TotalCarryingAmount}_g(t) + \text{Cash.LiabilityCashFlow}(t)}{\text{TotalCarryingAmount}_g(t - \Delta t)} - 1\end{aligned}$$ To fairly reflect the performance of the group, we add back in any liability payments made in the time step, and the denominator is the total carrying amount in the group at the beginning of the time step. Initial book return is set to zero: $$\text{TotalBookReturn}_g(0) = 0$$
TotalImpairmentProvision	The aggregate impairment provision for all the assets within the group that are subject to impairment. This output is reported in the currency of the group.
TotalImpairmentLoss	The change in impairment provision for all the assets within the group that are subject to impairment. This output is reported in the currency of the group.

Name	Description
TotalCurrencyTranslationGain	Absolute measure of gains or losses (if negative) that have occurred due to exchange rate movements at each time step, for all assets within the group (including cash invested in cash accounts). This output is reported in the currency of the group.
TotalDefaultLoss	The loss incurred when bonds in the group have defaulted over the time step. This output is reported in the currency of the group.
FairValue [AccountingConvention]	The aggregate fair value of all the assets within the group that are classified under the specified accounting convention (excludes cash in the cash account). This output is reported in the currency of the group.
CarryingAmount [AccountingConvention]	The aggregate book value of all the assets within the group that are classified under the specified accounting convention (excludes cash in cash accounts). This output is reported in the currency of the group.
RealisedGain [AccountingConvention]	Absolute measure of gains or losses (if negative) that have been realized at each time step, through sales of group assets that are classified under the specified accounting convention. This output is reported in the currency of the group.
RelativeRealisedGain [AccountingConvention]	Relative measure of gains or losses (if negative) that have been realized at each time step, through sales of group assets that are classified under the specified accounting convention.
RelativeUnrealisedGain [AccountingConvention]	Relative measure of gains or losses (if negative) that have not yet been realized at each time step, for assets within the group that are classified under the specified accounting convention.
UnrealisedGain [AccountingConvention]	Absolute measure of gains or losses (if negative) that have not yet been realized at each time step, for assets within the group that are classified under the specified accounting convention. This output is reported in the currency of the group.
OrdinaryIncome [AccountingConvention]	Investment income plus scheduled changes in carrying amount, for all assets within the group that are classified under the specified accounting convention (excludes cash invested in cash accounts). For MBS, it also includes the scheduled PrincipalPayments. This output is reported in the currency of the group.
ImpairmentProvision [AccountingConvention]	The aggregate impairment provision, for all the assets within the group that are classified under the specified accounting convention and are subject to impairment at each time step. This output is reported in the currency of the group.
ImpairmentLoss [AccountingConvention]	The change in impairment provision for all the assets within the group that are subject to impairment and classified under the specified accounting convention. This output is reported in the currency of the group.
DefaultLoss [AccountingConvention]	The loss incurred when bonds in the group, classified under the specified accounting convention, have defaulted over the time step. This output is reported in the currency of the group.
Vega	Measure of the change in value of the equity options due to a change in the implied volatility of the underlying equity. The vega of call/put option *i* is given by $\mathrm{Vega}_i(t) = \mathrm{EquityAsset.CapitalIndex}_i^*(t) \times e^{-\ln(1+EquityAsset.DividendYield_i(t))\times(T-t)} \times N_i'(d_1) \times \sqrt{T-t}$ where $N'(\cdot)$ is the density of standard normal distribution. Vega is negative when selling calls and puts. The vega of the portfolio is given by $\mathrm{Vega}(t) = \sum_i \mathrm{Vega}_i(t) \times \mathrm{NumberOfOptions}_i(t)$

Name	Description
Delta	Measure of the change in value of the equity options due to a change in the value of the underlying equity. The delta of call/put option *i* is given by $\text{Delta}_i(t)_{CALL} = e^{-\ln(1+EquityAsset.DividendYield(t))\times(T-t)} \times N_i(d1)$ $\text{Delta}_i(t)_{PUT} = -e^{-\ln(1+EquityAsset.DividendYield(t))\times(T-t)} \times N_i(-d1)$ The delta of the portfolio is given by $\text{Delta}(t) = \sum_i \text{Delta}_i(t) \times \text{NumberOfOptions}_i(t)$
TotalTransactionCosts	The aggregate amount paid out in transaction costs, over the time step, in the currency of the group. $\text{TotalTransactionCost}_g(t) = \sum_{p\in G_g} \text{TotalTransactionCost}_p(t) \times \frac{X_g(t)}{X_p(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy • $X_g(t)$ is the ExchangeRate.NominalValue of the economy of the group • The summation is over all portfolios
TotalPurchaseCosts	The aggregate amount paid out in transaction costs for assets purchased, over the time step, in the currency of the group.
TotalSaleCosts	The aggregate amount paid out in transaction costs for assets sold, over the time step, in the currency of the group.
Duration	The duration of the assets in the group. $\text{Duration}(t) = \frac{X_g(t)}{\text{FairValue}_g(t)} \times \sum_{p\in G_g} \frac{\text{FairValue}_p(t)}{X_p(t)} \times \text{Duration}_p(t)$ where $X_G(t)$ and $X_P(t)$ are the nominal exchange rates, with respect to the base economy, of the economy of the group and portfolio, respectively.
Convexity	The convexity of the assets in the group. $\text{Convexity}(t) = \frac{X_g(t)}{\text{FairValue}_g(t)} \times \sum_{p\in G_g} \frac{\text{FairValue}_g(t)}{X_p(t)} \times \text{Convexity}_p(t)$ where $X_G(t)$ and $X_P(t)$ are the nominal exchange rates, with respect to the base economy, of the economy of the group and portfolio, respectively.
DurationGap	The duration gap of the group. $\text{DurationGap}(t) = \text{Duration}_g(t) - \text{Duration}_l(t) \times \frac{\text{TotalLiabilityValue}_g(t)}{\text{TotalFairValue}_g(t)}$

Cash

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This model acts as the cash account for this portfolio group. Cash flows directed at this portfolio group are deposited in the cash account. Any cash left in the cash account after the payment of liabilities and application of any group rules at any time step is rolled up at the risk-free rate of the group economy to the next time step.

The group cash account can have a negative balance (TotalValue). A negative balance can happen in a time step where the required liability outflow exceeds the cash available within the group. If the group cash account has a negative balance at the end of a time step, the system uses all available cash, including cash available from sell on demand instructions, to pay down the debt and return the account to a positive state, before allowing any reinvestment.

Input variables

Name	Description
InitialCash	The cash held at the start of the simulation, in the currency of the group.

Outputs

Name	Description
TotalValue	The total amount held in the cash account, in the currency of the group. $$\begin{aligned}\text{TotalValue}(t) = {} & \text{TotalValue}(t-\Delta t) + \text{CashReturnInflow}(t) \\ & + \text{InvestmentIncome}(t) + \text{PrincipalPayments}(t) + \text{PrepaymentIncome}(t) \\ & + \text{RefinancingIncome}(t) + \text{CurrencyHedgeIncome}(t) + \text{DefaultRecoveryPayments}(t) \\ & + \text{GroupRulesInflow}(t) - \text{LiabilityOutflow}(t)\end{aligned}$$
CashReturnInflow	The interest received on the cash held in the account over the last time step, assuming that the cash is rolled up at the risk-free rate. $$\begin{aligned}&\text{CashReturnInflow}(t) \\ &\quad = \text{TotalValue}(t-\Delta t) \times (\exp(\text{ShortRate}(t-\Delta t) \times \Delta t) - 1)\end{aligned}$$ where ShortRate is the short rate output of the nominal yield curve of the economy of the group.
InvestmentIncome	Regular income from the assets, where the income is directed into the group cash account. This value includes income from coupons, dividends, rental income, and so on, reported in the currency of the group. MBS investment income is the interest part of the scheduled mortgage repayments installments received within the time step. $$\text{InvestmentIncome}(t) = \sum_{a \in G_g} C_a(t) \times \frac{X_g(t)}{X_a(t)}$$ where: • $C_a(t)$ is the income cash flow (that is, coupon, dividend, or rental income) received from an asset over the time step. • The summation is over all assets, *a*, held in the portfolios in the group, *g*. • X_a and X_g are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the group, respectively.

Name	Description
PrincipalPayments	Cash inflow from return of principal when bonds mature, where the inflow is directed into the group cash account. The principal payments from any MBS holdings are the principal part of the scheduled mortgage repayment installments received within the time step. This value is reported in the currency of the group. $$\text{PrincipalPayments}(t) = \sum_{a \in G_g} P_a(t) \times \frac{X_g(t)}{X_a(t)}$$ where: • $P_a(t)$ is the return of principal payment received from an asset over the time step. • The summation is over all assets, *a*, held in the portfolios of a group, *g*. • X_a and X_g are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the group, respectively.
PrepaymentIncome	Cash income from MBS prepayment, in the currency of the group. $$\text{PrepaymentIncome}(t) = \sum_i \text{UnitBalance}_i \times \text{UnitsHeld}_i(t) \times \text{Prepayment}_i(t) \times \frac{X_g(t)}{X_a(t)}$$ where $\text{Prepayment}_i(t)$ is the deterministic cash flow, based on the PSA prepayment schedule, for each MBS holding *i* within the group.
RefinancingIncome	Cash income from MBS refinancing, in the currency of the group. $$\text{RefinancingIncome}(t) = \sum_i \text{UnitBalance}_i \times \text{UnitsHeld}_i(t) \times \text{RefinancingCashflow}_i(t) \times \frac{X_g(t)}{X_a(t)}$$ where $\text{RefinancingCashflow}_i(t)$ is the stochastic refinancing cash flow for each MBS holding *i* within the group.
CurrencyHedgeIncome	Cash income received from the maturity of the currency forward contracts underlying currency hedged assets within the group, in the currency of the group. For more information about the calculation of this output, see the CurrencyHedging section of the *Scenario Generator Managed Portfolios Methodology Guide*.
DefaultRecoveryPayments	Cash recovered after the default of bonds, where the cash is directed into the group cash account. This value is reported in the currency of the group. $$\text{DefaultRecoveryPayments}(t) = \sum_{a \in G_g} R_a(t) \times \frac{X_g(t)}{X_a(t)}$$ where: • $R_a(t)$ is any recovery from the default of an asset over the time step. • The summation is over all assets, *a*, held in the portfolios of a group, *g*. • X_a and X_g are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the group, respectively.
GroupRulesInflow	Cash received from the application of group rules, in the currency of the group. A negative value indicates net cash outflow.

Name	Description
LiabilityOutflow	Cash paid out to cover liabilities in the time step, in the currency of the group. $$\text{LiabilityOutflow}(t) = X_G(\text{CashFlowTime}_i) \times \sum_i \frac{\text{CashFlow}_i}{X_{L_i}(\text{CashFlowTime}_i)} \times \exp(\text{ShortRate}_G(t-\Delta t) \times (t - \text{CashFlowTime}_i))$$ where: • $X_G(\text{CashFlowTime}_i)$ is the exchange rate (ExchangeRate.NominalValue) at the time of liability payment from the economy of the managed portfolio group. • $X_{L_i}(\text{CashFlowTime}_i)$ is the exchange rate (ExchangeRate.NominalValue) at the time of liability payment from the economy of the liability cash flow *i*. • The summation is over all liability cash flow models that needed to be paid since the previous time step, across all liability models. • ShortRate_G is the short rate from the yield curve from the economy of the managed portfolio group.

Rules

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Rules for the portfolio group.

Submodels

Name	Description
GroupCashControl	Defines a cash target and ideal minimum value for the group cash account, and optionally a maximum allowed cash balance and redistribution priorities.
EarningsTargetControl	Defines target earnings for the group.

Addable submodels

Name	Description
LiabilityTracking	Defines the portfolios that you want to rebalance to track selected characteristics of liabilities. Values are tracked in the currency of the group
RelativeProportion	Defines the distribution of assets across portfolios. Proportions are considered as relative.
AbsoluteProportion	Defines the proportions of group assets that should be invested in an individual portfolio.

Outputs

Name	Description
InfeasibleSolution	Returns 1 when a solution cannot be found that satisfies all of the inequality constraints within the rules that you have defined. For trials and time steps where an infeasible solution is found, any

Name	Description
	inequalities in the rules that you have defined are changed to equalities, and the rebalancing solver is run again with these modified objectives.
TargetEarnings	The target earnings value at the time step, in the currency of the group. • If **EarningsTargetControl.Enable** is **False**, returns 0. • If **EarningsTargetControl.Enable** is **True**, aggregates the earnings target values which are timed between the start and the end of the time step.

GroupCashControl

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This model enables you to assign a cash target, as a proportion or value, for the group cash account.

The software uses the minimum cash value that you set to determine how much cash to seek from the group portfolios.

If you select not to redistribute, then cash remains in the group cash account, and leaves only to pay liabilities.

If you select to redistribute, the software redistributes surplus cash to the managed portfolios at each time step according to the following:

Cash account value	Action
MinCash < Account value < **MaxCash**	No redistribution
Account value > **MaxCash**	Distribute surplus cash above the target according to the weights in **PayoutPriority**. This distribution happens before rebalancing.

Input variables

Name	Description	Conditions
TargetType	Select how you want to express the target group cash value: • **Value**—Absolute value • **Proportion**—Proportion of the total fair value of the group	
Target	The target group cash value.	
MinCash	Ideal minimum value of the account, expressed as a proportion of the target value.	
Redistribute	If you want to redistribute surplus cash to group portfolios, select **True**.	
MaxCash	Maximum value of the account, expressed as a proportion of the target value.	Enabled only if **Redistribute** is **True**.
PayoutPriority	Select the portfolios to which you want to direct cash. For each portfolio, fill the following: • **Portfolio**—The portfolio to which you want to direct cash. • **Proportion**—The proportion of cash that you want to direct to this portfolio.	Enabled only if **Redistribute** is **True**.

EarningsTargetControl

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to configure earnings targets. For more information about earnings targeting, see the [Earnings Targeting methodology].

Input variables

Name	Description
Enable	Possible values: • **True**—Enable earnings targeting. • **False**—Disable earnings targeting.
TargetEarnings	The target earnings over the projection period. For each maturity, fill the following fields: • **Term**—Expressed as an annual value. *For example*, for quarterly target earnings, enter the terms in multiples of 0.25. • **Target**—The earnings target, in the currency of the group.
MaxEarnings	An upper threshold for earnings, as a proportion of the target value. If earnings are between this value and the target, further sales are not required.
MinEarnings	A lower threshold for earnings, as a proportion of the target value. If earnings are between this value and the target, further sales are not required.

LiabilityTracking

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Define the portfolios that you want to rebalance to track selected characteristics of liabilities. Values are tracked in the currency of the group.

Input variables

Name	Description	Condition
RebalancingVariable	The value on which you want to base rebalancing. • **FairValue**—Rebalance on fair value.	
Portfolios	The managed portfolios to which you want to apply this rule.	
TrackedVariable	The liability value that you want to track. • **PresentValue**—Track the present value of liabilities.	
TrackedModel	The liability cash flow model that you want to track.	

Name	Description	Condition
ScalingFactor	The proportion of the variable that you want to track.	
ApplyConditions	To use this rule only when certain economic conditions are met or not met, select **True**. To always use this rule, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this rule. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the rule: • **ConditionsMet**—Use the rule when the **Conditions** are met. • **ConditionsNotMet**—Use the rule when the **Conditions** are not met.	
Weighting	A priority value. Any rule with a weighting of 1 or higher is a priority rule. Rules with a weighting under 1 are considered non-priority rules. The software attempts to satisfy as many priority rules as possible. The software compromises on non-priority rules according to their weightings. If two rules have the same weighting, then the software considers them in the order that they appear in the tree. The software can consider only *n*-1 priority rules, where *n* is the number of portfolios in the group. For more information about the rebalancing system, see the *Scenario Generator Managed Portfolios Methodology Guide*.	

RelativeProportion

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the distribution of assets across portfolio sets. Proportions defined in this rule are relative to each other. This rule makes no allowance for the proportions invested in portfolios not included in the rule.

Input variables

Name	Description	Condition
RebalancingVariable	The value on which you want to base rebalancing. • **FairValue**—Rebalance on fair value.	
Sets	Define the sets of portfolios to which you want to apply this rule. Fill the following fields: • **Portfolio**—Select the portfolios that appear in the set. • **Set**—A number for the set. Rows with the same set number make up a set.	
Proportions	Define the target proportions for asset allocations across sets. Proportions are relative to each other and must add to 1. For each allocation that you want to define, fill the following fields: • **Set**—The portfolio set, that you have defined under **Sets**. • **Target**—The target proportion of assets that you want to allocate to this set when rebalancing occurs.	

Name	Description	Condition
ApplyConditions	To use this rule only when certain economic conditions are met or not met, select **True**. To always use this rule, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this rule. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the rule: • **ConditionsMet**—Use the rule when the **Conditions** are met. • **ConditionsNotMet**—Use the rule when the **Conditions** are not met.	
Weighting	A priority value. Any rule with a weighting of 1 or higher is a priority rule. Rules with a weighting under 1 are considered non-priority rules. The software attempts to satisfy as many priority rules as possible. The software compromises on non-priority rules according to their weightings. If two rules have the same weighting, then the software considers them in the order that they appear in the tree. The software can consider only *n*-1 priority rules, where *n* is the number of portfolios in the group. For more information about the rebalancing system, see the *Scenario Generator Managed Portfolios Methodology Guide*.	

AbsoluteProportion

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the proportions of group assets that should be invested in an individual portfolio set.

Input variables

Name	Description	Condition
RebalancingVariable	The value on which you want to base rebalancing. • **FairValue**—Rebalance on fair value.	
Sets	Define the sets of portfolios to which you want to apply this rule. Fill the following fields: • **Portfolio**—Select the portfolios that appear in the set. • **Set**—A number for the set. Rows with the same set number make up a set.	
Proportions	Define the target proportion for asset allocations into individual sets. For each allocation that you want to define, fill the following fields: • **Set**—The portfolio set, that you have defined under **Sets**. • **Operator**—The operator for this proportion (=, ≤, or ≥). • **Target**—The target proportion of group assets that you want to allocate to this set when rebalancing occurs.	
ApplyConditions	To use this rule only when certain economic conditions are met or not met, select **True**. To always use this rule, select **False**.	

Name	Description	Condition
Conditions	Select the TradingCondition that you want to apply to this rule. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the rule: • **ConditionsMet**—Use the rule when the **Conditions** are met. • **ConditionsNotMet**—Use the rule when the **Conditions** are not met.	
Weighting	A priority value. Any rule with a weighting of 1 or higher is a priority rule. Rules with a weighting under 1 are considered non-priority rules. The software attempts to satisfy as many priority rules as possible. The software compromises on non-priority rules according to their weightings. If two rules have the same weighting, then the software considers them in the order that they appear in the tree. The software can consider only *n*-1 priority rules, where *n* is the number of portfolios in the group. For more information about the rebalancing system, see the *Scenario Generator Managed Portfolios Methodology Guide*.	

ManagedPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The Managed Portfolio model comprises initial asset holdings, a cash account, buy, sell and on demand sell instructions.

Note Cash flows directed outside of this portfolio, or received from other portfolios within the group, affect the calculation of the following outputs.

Submodels

Name	Description
Cash	This model acts as the cash account for cash flows for this portfolio.
InitialHoldings	Defines the time 0 asset holdings of the portfolio.
InvestmentStrategy	Contains the buy, sell, and on-demand sell instructions that make up the investment strategy of the portfolio.

Input variables

Name	Description	Condition
Economy	The economy of the managed portfolio.	
FairValueCalculationMethod	From the drop-down list, select the calculation method that you want to use for the fair value of any bonds in the portfolio. • **ModelledFairValue**—The fair value at the start of the projection is reported as the ESG calculated value of the bond holdings.	

Name	Description	Condition
	• **FairValueDefinedScalingPeriod**—The fair value at the start of the projection is reported as the input fair value of the bond holdings. A spread is added to the bond discount rate, which the software removes over the scaling period. • **FairValueScalingPeriodByMaturity**—The fair value at the start of the projection is reported as the input fair value of the bond holdings. A spread is added to the bond discount rate, which the software removes over the lifetime of each bond.	
ScalingPeriod	The scaling period over which the software removes the spread from the bond discount rate.	Enabled only if **FairValueCalculationMethod** is **FairValueDefinedScalingPeriod**
BondImpairments	Select the bond impairment events that are valid for this portfolio. These impairments can be bond or common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The bond or common impairment event. • **LogicalOperator**—**AND** or **OR**. For the **IAS** Accounting Methodology, these events will determine when a bond should be impaired, and therefore whether an impairment provision should be calculated. For the **IFRS** Accounting Methodology, these events will determine when a bond should move between Stage 1 and Stage 2, and determines which calculation for impairment provision should be used.	
EquityImpairments	Select the equity impairment events that are valid for this portfolio, from the common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The common impairment event. • **LogicalOperator**—**AND** or **OR**.	
PropertyImpairments	Select the property impairment events that are valid for this portfolio, from the common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The common impairment event. • **LogicalOperator**—**AND** or **OR**.	
FundImpairments	Select the fund impairment events that are valid for this portfolio, from the common impairment events, that you have set up previously. For each impairment, fill the following fields: • **Impairment**—The common impairment event. • **LogicalOperator**—**AND** or **OR**.	

Outputs

Name	Description
TotalFairValue	The market value of the portfolio. This value reflects the entire portfolio including all assets currently held, and any cash in the cash account. $$\mathrm{FairValue}_p(t) = \mathrm{Cash}_p.\mathrm{TotalValue} + \sum_{a \in P_p} \mathrm{FairValue}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $\mathrm{Cash}_p.\mathrm{TotalValue}$ is the balance of the cash account in the managed portfolio.

Name	Description
	• X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
TotalFairValueReturn	The total of the fair value return across all assets held by the portfolio, *p*, regardless of accounting convention. $\text{TotalFairValueReturn}_p(t) = \frac{\text{TotalFairValue}_p(t) - \text{AssetCashIn}(t) + \text{AssetCashOut}(t) - \text{RebalancingCashFlow}(t)}{\text{TotalFairValue}(t - \Delta t)} - 1$ To fairly reflect the performance of the portfolio, the fair value return is adjusted as described below. The software also makes an adjustment for the rebalancing cash received: • Any cash flows generated by the assets in the portfolio that have been directed to another cash account are added on. • Any cash flows directed into this portfolio from assets belonging to another portfolio are subtracted off. • Any cash received by the portfolio cash account from the rebalancing solver (that is, the GroupRulesInflow, which is defined to be positive going into the portfolio) is subtracted off. The initial fair value return is zero: $\text{TotalFairValueReturn}_p(0) = 0$.
Duration	The duration of the portfolio. Duration is addable and for a portfolio can be derived by weighting the duration of each instrument by its share in the fair value when converted to a single currency, usually the currency of the managed portfolio. The duration of portfolio *p* is: $\text{Duration}_p(t) = \frac{X_p(t)}{\text{FairValue}_p(t)} \times \sum_{a \in P_p} \frac{\text{FairValue}_a(t)}{X_a(t)} \times \text{Duration}_a(t)$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively. **Note** Cash has duration of zero and hence contributes to FairValue *p* but not the summation in the equation above. The end result of an increasing cash balance (*for example*, to a very large value) is a reduction of the duration (that is, to a very small positive value). When we have multiple instruments from different currencies and different credit ratings, the duration can be interpreted as a sensitivity to a parallel shift of all reference yield curves.
Convexity	Portfolio convexity can be derived by weighting the convexity of each instrument by its share in the fair value when converted to a single currency, usually the currency of the managed portfolio. The convexity of the portfolio, *p*, is: $\text{Convexity}_p(t) = \frac{X_p(t)}{\text{FairValue}_p(t)} \times \sum_{a \in P_p} \frac{\text{FairValue}_a(t)}{X_a(t)} \times \text{Convexity}_a(t)$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively. **Note** Cash has convexity of zero and hence contributes to FairValue *p* but not the summation in the equation above. The end result of an increasing cash balance (*for example*, to a very large value) is a reduction of the convexity (that is, to a very small positive value).

Name	Description
TotalCarryingAmount	The net carrying amount of the assets, including cash, in the portfolio, regardless of accounting convention. This value reflects the entire portfolio including all assets currently held, and any cash in the cash account. $$\text{CarryingAmount}_p(t) = \text{Cash}_p.\text{TotalValue} + \sum_{a \in P_p} \text{CarryingAmount}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $\text{Cash}_p.\text{TotalValue}$ is the balance of the cash account in the managed portfolio. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
TotalRealisedGain	Absolute measure of gains or losses (if negative) that have been realized. Defined below, in the currency of the portfolio, for all assets sold at the time step. $$\text{TotalRealisedGain}(t) = \sum_{a \in P_p}^{sold(t-\Delta t,t)} \text{RealisedGain}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio respectively. **Note** $$\text{TotalRealisedGain}(t) = \text{InvestmentStrategy.TotalGainsRealised} - \text{InvestmentStrategy.TotalLossesRealised}$$ For the asset level calculation of realized gain under IAS/IFRS accounting methodology, see the *Scenario Generator Managed Portfolios Methodology Guide*.
TotalRelativeRealisedGain	Relative measure of gains or losses (if negative) that have been realized over the time step. $$\text{TotalRelativeRealisedGain}(t) = \frac{\text{TotalRealisedGain}_p(t)}{\sum_{a \in P_p}^{sold(t-\Delta t,t)} \text{CarryingAmount}_a(t) \times \frac{X_p(t)}{X_a(t)}}$$
TotalRelativeUnrealisedGain	Relative measure of gains or losses (if negative) that have not yet been realized. $$\text{TotalRelativeUnrealisedGain}(t) = \frac{\text{TotalUnrealisedGain}(t)}{\text{TotalCarryingAmount}(t)}$$
TotalUnrealisedGain	Absolute measure of gains or losses (if negative) that have not been realized. This measure reflects the amount that would have been realized if the assets had been sold at the particular time step. Defined below, in the currency of the portfolio, for all assets held within the portfolio at the end of the time step (including cash). $$\text{TotalUnrealisedGain}(t) = \sum_{a \in P_p}^{sold(t-\Delta t,t)} \text{UnrealisedGain}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio respectively. **Note** $$\text{TotalUnrealisedGain}(t) = \text{TotalGainsUnrealised}(t) - \text{TotalLossesUnrealised}(t)$$ For the asset level calculation of unrealized gain under IAS/IFRS accounting methodology, see the *Scenario Generator Managed Portfolios Methodology Guide*.
TotalGainsUnrealised	Absolute measure of gains that have not been realized at the time step, reported in the currency of the portfolio.
TotalLossesUnrealised	Absolute measure of losses that have not been realized at the time step, reported in the currency of the portfolio.

Name	Description
TotalOrdinaryIncome	Investment income received in the form of coupons, dividends, or rental income (dependent on asset type), including the return on any cash invested in the cash account, plus the scheduled change in carrying amount for assets classified under specified accounting conventions, in the currency of the portfolio. For MBS, it also includes the scheduled PrincipalPayments. **Note** When bonds mature, the nominal value is collected as cash, and this cash is not recognized as ordinary income. $$\mathrm{TotalOrdinaryIncome}(t) = \sum_{a \in P_p} \mathrm{OrdinaryIncome}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • For assets classified as FairValuePNL, FairValueOCI, and HistoricalCost, $$\mathrm{OrdinaryIncome}_a(t) = \mathrm{InvestmentIncome}_a(t)$$ • For assets classified as EffectiveInterestRateAmortisation, LinearAmortisation, DecliningBalanceDepreciation, LinearDepreciation, $$\mathrm{OrdinaryIncome}_a(t) = \mathrm{InvestmentIncome}_a(t) + \mathrm{CarryingAmount}_a(t) - \mathrm{CarryingAmount}_a(t - \Delta t)$$ • For MBS assets, $$\mathrm{OrdinaryIncome}_a(t) = \mathrm{InvestmentIncome}_a(t) + \mathrm{PrincipalPayments}_a(t)$$ • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
TotalEarnings	The earnings value at each time step, reported in the currency of the portfolio. $$\mathrm{TotalEarnings}(t) = \mathrm{TotalOrdinaryIncome}(t) - \mathrm{TotalDefaultLoss}(t) - \mathrm{TotalImpairmentLoss}(t) + \mathrm{TotalRealisedGain}(t) + \mathrm{CurrencyHedgeIncome}(t) + \sum_{FairValuePNLa \in P_p} \left(\mathrm{CarryingAmount}_a(t) - \mathrm{CarryingAmount}_a(t - dt)\right) \times \frac{X_p(t)}{X_a(t)}$$ When using asymmetric output settings, this output will equal the sum of the TotalEarnings (calculated using the equation above) at each of the intermediate timesteps.
TotalBookReturn	The total of the book return across all assets held by the portfolio, *p*, regardless of accounting convention. $$\mathrm{TotalBookReturn}_p(t) = \frac{\mathrm{TotalCarryingAmount}_p(t) - \mathrm{AssetCashIn}(t) + \mathrm{AssetCashOut}(t) - \mathrm{RebalancingCashFlow}(t)}{\mathrm{TotalCarryingAmount}_p(t - \Delta t)} - 1$$ To fairly reflect the performance of the portfolio, the book return is adjusted as described below. The software also makes an adjustment for the rebalancing cash received: • Any cash flows generated by the assets in the portfolio that have been directed to another cash account are added on. • Any cash flows directed into this portfolio from assets belonging to another portfolio are subtracted off. • Any cash received by the portfolio cash account from the rebalancing solver (that is, the GroupRulesInflow, which is defined to be positive going into the portfolio) is subtracted off. The initial book return is zero: $$\mathrm{TotalBookReturn}_p(0) = 0$$

Name	Description
TotalImpairmentProvision	The total impairment provision at each time step, reported in the currency of the portfolio. $$\text{ImpairmentProvision}(t) = \sum_{a \in P_p} \text{ImpairmentProvision}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively. For the asset level calculation of impairment provision under IAS/IFRS accounting methodology, see the *Scenario Generator Managed Portfolios Methodology Guide*.
TotalImpairmentLoss	The change in impairment provision for all the assets within the portfolio that are subject to impairment. This output is reported in the currency of the portfolio.
TotalCurrencyTranslationGain	Absolute measure of gains or losses (if negative) that have occurred due to exchange rate movements at each time step, for all assets within the portfolio (including cash invested in the cash account). This output is reported in the currency of the portfolio.
TotalDefaultLoss	The loss incurred when bonds in the portfolio have defaulted over the time step. This output is reported in the currency of the portfolio.
FairValue [AccountingConvention]	The aggregate fair value of all the assets within the portfolio that are classified under the specified accounting convention (excludes cash in the cash account). This output is reported in the currency of the portfolio.
CarryingAmount [AccountingConvention]	The aggregate book value of all the assets within the portfolio that are classified under the specified accounting convention (excludes cash in the cash account). This output is reported in the currency of the portfolio.
RealisedGain [AccountingConvention]	Absolute measure of gains or losses (if negative) that have been realized at each time step, through sales of portfolio assets that are classified under the specified accounting convention. This output is reported in the currency of the portfolio.
RelativeRealisedGain [AccountingConvention]	Relative measure of gains or losses (if negative) that have been realized at each time step, through sales of portfolio assets that are classified under the specified accounting convention.
RelativeUnrealisedGain [AccountingConvention]	Relative measure of gains or losses (if negative) that have not yet been realized at each time step, for assets within the portfolio that are classified under the specified accounting convention.
UnrealisedGain [AccountingConvention]	Absolute measure of gains or losses (if negative) that have not yet been realized at each time step, for assets within the portfolio that are classified under the specified accounting convention. This output is reported in the currency of the portfolio.
OrdinaryIncome [AccountingConvention]	Investment income plus scheduled changes in carrying amount, for all assets within the portfolio that are classified under the specified accounting convention (excludes cash invested in the cash account). For MBS, it also includes the scheduled PrincipalPayments. This output is reported in the currency of the portfolio.
ImpairmentProvision [AccountingConvention]	The impairment provision, for all assets within the portfolio that are classified under the specified accounting convention and are subject to impairment, at each time step. This output is reported in the currency of the portfolio.
ImpairmentLoss [AccountingConvention]	The change in impairment provision for all the assets within the portfolio that are subject to impairment and classified under the specified accounting convention. This output is reported in the currency of the portfolio.
DefaultLoss [AccountingConvention]	The loss incurred when bonds in the portfolio, classified under the specified accounting convention, have defaulted over the time step. This output is reported in the currency of the portfolio.

Name	Description
Vega	Measure of the change in value of the equity options due to a change in the implied volatility of the underlying equity. The vega of call/put option *i* is given by $\text{Vega}_i(t) = \text{EquityAsset.CapitalIndex}_i^*(t) \times e^{-\ln(1+\text{EquityAsset.DividendYield}_i(t))\times(T-t)} \times N_i'(d_1) \times \sqrt{\text{T}-t}$ where $N'(\cdot)$ is the density of standard normal distribution and T the maturity. Vega is negative when selling calls and puts. The vega of the portfolio is given by $\text{Vega}(t) = \sum_i \text{Vega}_i(t) \times \text{NumberOfOptions}_i(t)$
Delta	Measure of the change in value of the equity options due to a change in the value of the underlying equity. The delta of call/put option *i* is given by $\text{Delta}_i(t)_{CALL} = e^{-\ln(1+EquityAsset.DividendYield(t))\times(T-t)} \times N_i(d1)$ $\text{Delta}_i(t)_{PUT} = -e^{-\ln(1+EquityAsset.DividendYield(t))\times(T-t)} \times N_i(-d1)$ The delta of the portfolio is given by $\text{Delta}(t) = \sum_i \text{Delta}_i(t) \times \text{NumberOfOptions}_i(t)$

Cash

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The cash account keeps track of the cash that is held within the managed portfolio. In general terms, the cash balance increases when cash is received from assets held in the portfolio (interest payments, dividends, rental income, maturities, and recovery from default) and also when assets are sold. Conversely, the cash balance decreases when cash is used to buy assets, but the net amount in the cash account cannot go negative.

Any cash left in the cash account after application of the buy instructions at any time step is rolled up at the risk-free rate of the portfolio economy to the next time step.

Input variables

Name	Description
InitialCash	The amount of cash held in the portfolio at the start of the simulation, in the currency of the portfolio.

Outputs

Name	Description
TotalValue	The total value of cash in this portfolio, in the currency of the portfolio. $$\begin{aligned}\mathrm{TotalValue}(t) = {} & \mathrm{TotalValue}(t-\Delta t) + \mathrm{CashReturnInflow}(t) \\ & + \mathrm{InvestmentInterest}(t) + \mathrm{PrincipalPayments}(t) + \mathrm{PrepaymentIncome}(t) \\ & + \mathrm{RefinancingIncome}(t) + \mathrm{CurrencyHedgeIncome}(t) + \mathrm{DefaultRecoveryPayments}(t) \\ & + \mathrm{InvestmentStrategyNetInflow}(t) + \mathrm{GroupRulesInflow}(t)\end{aligned}$$
CashReturnInflow	The interest received on the cash held in the portfolio over the last time step, assuming that the cash is rolled up at the risk-free rate. $$\begin{aligned}&\mathrm{CashReturnInflow}(t) \\ &\quad = \mathrm{TotalValue}(t-\Delta t) \times (\exp(\mathrm{ShortRate}(t-\Delta t) \times \Delta t) - 1)\end{aligned}$$ where ShortRate is the short rate output of the nominal yield curve of the economy of the managed portfolio.
InvestmentIncome	Regular income from the assets held in the portfolio, including coupons, dividends, rental income, and so on, reported in the currency of the portfolio. MBS investment income is the interest part of the scheduled mortgage repayments installments received within the time step. $$\mathrm{InvestmentIncome}(t) = \sum_{a \in P_p} C_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $C_a(t)$ is the income cash flow (that is, coupon, dividend, or rental income) received from an asset over the time step. • The summation is over all assets, *a*, held in the portfolio, *p*. • If the account also receives income cash from other portfolio units within the group, the summation is over all appropriate assets in the group. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
PrincipalPayments	Cash inflow from return of principal when bonds mature, in the currency of the portfolio. The principal payments from any MBS holdings are the principal part of the scheduled mortgage repayment installments received within the time step. $$\mathrm{PrincipalPayments}(t) = \sum_{a \in P_p} P_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $P_a(t)$ is the return of principal payment received from an asset over the time step. • The summation is over all assets, *a*, held in the portfolio, *p*. • If the account also receives principal payments from other portfolio units within the group, the summation is over all appropriate assets in the group. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
PrepaymentIncome	Cash income from MBS prepayment, in the currency of the portfolio. $$\begin{aligned}\mathrm{PrepaymentIncome}(t) = \sum_i \mathrm{UnitBalance}_i \times \mathrm{UnitsHeld}_i(t) \\ \times \mathrm{Prepayment}_i(t) \times \frac{X_p(t)}{X_a(t)}\end{aligned}$$ where $\mathrm{Prepayment}_i(t)$ is the deterministic cash flow, based on the PSA prepayment schedule, for each MBS holding *i* within the portfolio.

Name	Description
RefinancingIncome	Cash income from MBS refinancing, in the currency of the portfolio. $$\mathrm{RefinancingIncome}(t) = \sum_i \mathrm{UnitBalance}_i \times \mathrm{UnitsHeld}_i(t) \times \mathrm{RefinancingCashflow}_i(t) \times \frac{X_p(t)}{X_a(t)}$$ where $\mathrm{RefinancingCashflow}_i(t)$ is the stochastic refinancing cash flow for each MBS holding *i* within the portfolio.
CurrencyHedgeIncome	Cash income received from the maturity of the currency forward contracts underlying currency hedged assets within the portfolio, in the currency of the portfolio. For more information about the calculation of this output, see the CurrencyHedging section of the *Scenario Generator Managed Portfolios Methodology Guide*.
DefaultRecoveryPayments	Cash recovered after the default of bonds, in the currency of the portfolio. $$\mathrm{DefaultRecoveryPayments}(t) = \sum_{a \in P_p} R_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • $R_a(t)$ is any recovery from the default of an asset over the time step. • The summation is over all assets, *a*, held in the portfolio, *p*. • If the account also receives recovery payments from other portfolio units within the group, the summation is over all appropriate assets in the group. • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.
InvestmentStrategyNetInflow	Net cash received from all buy and sell instructions, including: • Positive amounts from the sale of instruments • Negative amounts from the purchase of instruments
GroupRulesInflow	Cash received from application of the group rules, in the currency of the managed portfolio. A negative value indicates cash outflow.

InitialHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and respective accounting conventions for the assets in the managed portfolio.

Addable submodels

Name	Description
FixedCouponSpecificBondHoldings	Defines the time zero holdings and accounting convention for specific issuer bonds in the managed portfolio.
FixedCouponGenericBondHoldings	Defines the time zero holdings and accounting convention for generic issuer bonds in the managed portfolio.
EquityHoldings	Defines the time zero holdings and accounting convention for equity assets in the managed portfolio.

Name	Description
FundHoldings	Defines the time zero holdings and accounting convention for funds in the managed portfolio.
PropertyHoldings	Defines the time zero holdings and accounting convention for property assets in the managed portfolio.
EquityOptionHoldings	Defines the time zero holdings for equity options in the managed portfolio.
MBSHoldings	Defines the time zero holdings for mortgage-backed securities in the managed portfolio.

FixedCouponSpecificBondHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for specific issuer bonds in the managed portfolio.

Input variables

Name	Description
FixedCouponSpecificBondHoldings	Define the specific bond holdings at time zero. For each holding, fill the following fields: • **Name**—The name of the holding. • **Issuer**—The specific issuer for the bond. For more information about SpecificIssuers, see SpecificIssuers. • **Economy**—Defines the currency in which the bonds are issued, which can be different from the economy of the issuer. This value defines the yield curve that the software uses for discounting payments. • **NumberOfBonds**—The number of bonds held. • **TotalNominalValue**—The total nominal value, for all bonds. *For example*, if TotalNominalValue is 500 and NumberOfBonds is 5, then the nominal value per bond is 100. • **TotalInitialFairValue**—The total initial fair value, for all bonds, in the currency of the bond assets. • **TotalInitialCarryingAmount**—The total initial carrying amount, for all bonds, in the currency of the bond assets. • **Type**—**Nominal** or **IndexLinked**. • **Term**—The term to maturity of the bonds. • **Coupon**—The annual coupon rate of the bonds. • **Frequency**—The number of coupon payments per year. • **Seniority**—The seniority of the bonds. • **AccountingConvention**—The accounting convention for the bonds. For more information about accounting conventions, see AccountingConventions • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged.
PrincipalCashflowTarget	The cash account to which you want to direct maturity payments from the bonds.

Name	Description
InterestCashflowTarget	The cash account to which you want to direct coupon payments from the bonds.
DefaultCashflowTarget	The cash account to which you want to direct default payments from the bonds.
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.

FixedCouponGenericBondHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for generic issuer bonds in the managed portfolio.

Input variables

Name	Description
FixedCouponGenericBondHoldings	Define the generic bond holdings at time zero. For each holding, fill the following fields: • **NumberOfIssuers**—The number of issuers for this holding. • **CreditClass**—The credit class for this holding. • **CreditModel**—The credit model for this holding. • **EquityAsset**—The equity asset for this holding. **Note** CreditClass, CreditModel, and EquityAsset define the bond issuers. • **Economy**—The currency in which the bonds are issued, which can be different from the economy of the issuer. This value defines the yield curve that the software uses for discounting payments. • **TotalNumberOfBonds**—The total number of bonds, which must be an integer multiple of NumberOfIssuers. Each issuer issues a number of bonds equal to TotalNumberOfBonds/ NumberOfIssuers. • **TotalNominalValue**—The total nominal value, for all bonds. *For example*, if TotalNominalValue is 500 and TotalNumberOfBonds is 5, then the nominal value per bond is 100. • **TotalInitialFairValue**—The total initial fair value, for all bonds, in the currency of the bond assets. • **TotalInitialCarryingAmount**—The total initial carrying amount, for all bonds, in the currency of the bond assets. • **Type**—**Nominal** or **IndexLinked**. • **Term**—The term to maturity of the bonds. • **Coupon**—The annual coupon rate of the bonds. • **Frequency**—The number of coupon payments per year. • **Seniority**—The seniority of the bonds. • **AccountingConvention**—The accounting convention for the bonds. For more information about accounting conventions, see AccountingConventions • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged.

Name	Description
PrincipalCashflowTarget	The cash account to which you want to direct maturity payments from the bonds.
InterestCashflowTarget	The cash account to which you want to direct coupon payments from the bonds.
DefaultCashflowTarget	The cash account to which you want to direct default payments from the bonds.
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.

EquityHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for equity assets in the managed portfolio.

Input variables

Name	Description
EquityHoldings	Define the equity asset holdings at time zero. For each holding, fill the following fields: • **EquityAsset**—The equity asset for the holding. For more information about equity assets, see EquityAssets. • **TotalInitialFairValue**—The initial fair value for the holding, in the currency of the asset. • **TotalInitialCarryingAmount**—The total initial carrying amount for the holding, in the currency of the asset. • **AccountingConvention**—The accounting convention for the equity holding. For more information about accounting conventions, see AccountingConventions. • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged. **Note** Equity holdings are sold in integer numbers of shares, and the number of shares held is determined by TotalInitialFairValue / time zero equity price. If this calculation does not produce an integer number of shares at time zero, the software rounds the fair value down to the nearest integer share number, and deposits excess fair value as cash.
IncomeCashflowTarget	The cash account to which you want to direct regular income payments from the equity assets.
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.

FundHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for funds in the managed portfolio.

Input variables

Name	Description
FundHoldings	Define the fund holdings at time zero. For each holding, fill the following fields: • **FundAsset**—The fund asset for this holding. • **TotalInitialFairValue**—The initial fair value for this holding, in the currency of the asset. • **TotalInitialCarryingAmount**—The total initial carrying amount for this holding, in the currency of the asset. • **AccountingConvention**—The accounting convention for the fund holding. For more information about accounting conventions, see AccountingConventions. • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02.
IncomeCashflowTarget	The cash account to which you want to direct regular income payments from the fund assets.

PropertyHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings and accounting convention for property assets in the managed portfolio.

Input variables

Name	Description
PropertyHoldings	Define the property holdings at time zero. For each holding, fill the following fields: • **PropertyAsset**—The property asset for the holding. Property assets are defined under ESG.Assets.EquityAssets. • **NumberOfUnits**—The number of units that make up the holding. • **TotalInitialFairValue**—The initial fair value for the holding, in the currency of the asset. • **TotalInitialCarryingAmount**—The total initial carrying amount for the holding, in the currency of the asset. • **AccountingConvention**—The accounting convention for the property holding. For more information about accounting conventions, see AccountingConventions. • **AlreadyImpaired**—Select whether the holding is already impaired at the start of the projection. • **SmoothingMeanAge**—The intended mean age (in years) of the data weightings for the smoothing functionality. This value must be greater than or equal to zero. A value of zero indicates no smoothing. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged. **Note** Property holdings are sold in units, and the fair value of a unit at time zero is defined as TotalInitialFairValue / NumberOfUnits.

Name	Description
IncomeCashflowTarget	The cash account to which you want to direct regular income payments from the property assets.
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.

EquityOptionHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the equity options held at time zero.

Input variables

Name	Description
EquityOptionHoldings	Define the equity option holdings at time zero. For each holding, fill the following fields: • **OptionType**—**Call** or **Put**. • **Position**—**Long** or **Short**. • **UnderlyingImpliedVolModel**—From the drop-down list, select a RWOptionImpliedVolatility model that you have set up. For more information, see RWOptionImpliedVolatility. • **Maturity**—Term to maturity of the option in years. • **Strike**—Strike price of the option as a proportion of the time 0 equity asset index, where the asset is defined by **UnderlyingImpliedVolModel**. • **TotalNotional**—Time 0 notional value of the option contracts. • **Settlement**—**Cash** or **Physical**. Determines whether the position is settled at maturity through the exchange of physical equity or cash.
IncomeCashflowTarget	Cash account to which you want to direct regular income from the assets.
PhysicalSettlementPortfolios	The portfolios with which you want to physically settle equity options, where **Settlement** for the holding is **Physical**. For each portfolio, fill the following fields: • **Portfolio**—The portfolio with which to settle. • **Order**—The priority order of portfolios for physical settlement. A lower number denotes higher priority. If the highest priority portfolio does not have sufficient appropriate equity, the software uses the next highest, and so on. If there is not enough equity across the portfolios, the software uses cash settlement. Order must be unique.

MBSHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the time zero holdings for mortgage-backed securities in the managed portfolio. MBS holdings pay out cash flows (interest, principal, prepayment, and refinancing) as they occur with the same frequency as the time step of the simulation.

Input variables

Name	Description
MBSHoldings	Define the mortgage-backed security holdings at time zero. For each holding, fill the following fields: • **Issuer**—The MBS issuer for the holding. For more information about configuring mortgage-backed securities, see MBSIssuer. • **MtgeTerm**—The term of the mortgages in the underlying mortgage pool. • **MtgeCoupon**—The weighted average coupon of the mortgages in the pool. This value is equivalent to a weighted average of the fixed rates paid by the mortgage holders. The payments for the mortgages are monthly. • **Age**—The weighted average age, in months, of the mortgages at the start of the simulation. • **SurvivalFactor**—The survival factor. • **MBSCoupon**—The MBS coupon. • **OASMtge**—The option adjusted spread of the mortgages in the mortgage-backed security. • **NumberOfUnits**—The number of units that make up the holding. • **MBSBalanceAtIssue**—The balance of the mortgages underlying the MBS holding at its date of issue, in the currency of the asset. • **SaleCost**—The proportional transaction cost on the sale of the holding. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the holding are currency hedged.
InterestCashflowTarget	The cash account to which you want to direct regular income from the assets.
PrincipalCashflowTarget	The cash account to which you want to direct principal payments from the assets.
PrepaymentCashflowTarget	The cash account to which you want to direct cash flows from prepayment from the assets.
RefinancingCashflowTarget	The cash account to which you want to direct cash flows from refinancing from the assets.
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.

InvestmentStrategy

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the buy and sell instructions that make up the investment strategy. For assets within managed portfolios, in a managed portfolio group, you can also use on-demand sell instructions. These instructions are followed only if extra cash is required for rebalancing or payment of liabilities.

Addable submodels

Name	Description
BondSellInstruction	Defines the characteristics of bond assets that must be sold at any time step as the projection progresses.
BondOnDemandSellInstruction	Defines the characteristics of bond assets that can be sold at any time step, to pay liabilities or achieve rebalancing objectives.

Name	Description
BondBuyInstruction	Defines which bond assets to buy as the projection progresses.
EquitySellInstruction	Defines the characteristics of equity assets that must be sold at any time step as the projection progresses.
EquityOnDemandSellInstruction	Defines the characteristics of equity assets that can be sold at any time step, to pay liabilities or achieve rebalancing objectives.
EquityBuyInstruction	Defines which equity assets to buy as the projection progresses.
FundSellInstruction	Defines the characteristics of fund assets that must be sold at any time step as the projection progresses.
FundOnDemandSellInstruction	Defines the characteristics of fund assets that can be sold at any time step, to pay liabilities or achieve rebalancing objectives.
FundBuyInstruction	Defines which fund assets to buy as the projection progresses.
PropertySellInstruction	Defines the characteristics of property assets that must be sold at any time step as the projection progresses.
PropertyOnDemandSellInstruction	Defines the characteristics of property assets that can be sold at any time step, to pay liabilities or achieve rebalancing objectives.
PropertyBuyInstruction	Defines which property assets to buy as the projection progresses.
MBSSellInstruction	Defines the characteristics of MBS assets that must be sold at any time step as the projection progresses.
MBSOnDemandSellInstruction	Defines the characteristics of MBS assets that can be sold at any time step, to pay liabilities or achieve rebalancing objectives.
MBSBuyInstruction	Defines which MBS assets to buy as the projection progresses.

Outputs

Name	Description
TotalValueBought	Aggregate of the ValueBought outputs from the individual buy rules in the InvestmentStrategy submodels.
TotalValueSold	Aggregate of the ValueSold outputs from the individual sell rules in the InvestmentStrategy submodels.
TotalGainsRealised	Absolute measure of gains realized at each time step, through sales of portfolio assets. Reported in the currency of the managed portfolio.
TotalLossesRealised	Absolute measure of losses realized at each time step, through sales of portfolio assets. Reported in the currency of the managed portfolio.
InvestmentStrategyNetInflow	TotalValueSold - TotalValueBought.
TotalTransactionCosts	The aggregate amount paid out in transaction costs, over the time step, in the currency of the portfolio. $$\mathrm{TotalTransactionCosts}_p(t) = \sum_j \mathrm{TransactionCosts}_j(t)$$ where the summation is over all of the buy, sell, and on demand sell instructions within the portfolio.

Name	Description
TotalPurchaseCosts	The aggregate amount paid out in costs for assets purchased, over the time step, in the currency of the portfolio.
TotalSaleCosts	The aggregate amount paid out in costs for assets sold, over the time step, in the currency of the portfolio.

BondSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A bond sell instruction defines the characteristics of bonds that must be sold at each time step. In a single bond sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of bonds, set up multiple BondSellInstructions. In other words, for a logical AND, use a single bond sell instruction with multiple conditions. For a logical OR, use multiple bond sell instructions.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of bonds. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. Select **Term**, **CreditClassIndex**, **Duration**, **Convexity**, **FairValueRedemptionYield**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic. If you use the **CreditClassIndex** characteristic, the mappings to credit classes are as follows: • **0**—Govt • **1**—AAA • **2**—AA • **3**—A • **4**—BBB • **5**—BB • **6**—B • **7**—CCC • **8**—Default

Outputs

Name	Description
BondsSold	The number of bonds sold over the time step.

Name	Description
ValueSold	The value of the bonds sold over the time step, in the currency of the managed portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\mathrm{TransactionCosts}(t) = \mathrm{AssetsSold}_i(t) \times \mathrm{AssetPrice}_i^*(t) \times \mathrm{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

BondOnDemandSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An on-demand bond sell instruction defines conditions for the sale of bonds, if extra cash is required to support rebalancing or the payment of liabilities. The preset configuration is that any asset of this type in the portfolio is available for sale. You can change this configuration to define conditions of sale. In a single bond sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of bonds, set up multiple BondOnDemandSellInstructions. In other words, for a logical AND, use a single on-demand bond sell instruction with multiple conditions. For a logical OR, use multiple on-demand bond sell instructions.

For on-demand bond sell instructions, you can also define the order in which to sell the bonds.

Input variables

Name	Description	Condition
SellAnyAsset	Specify whether you want to make all assets available for sale on demand. Possible values: • **True**—Any asset is available for sale on demand. • **False**—Only the assets that you specify in **SellInstruction** are available for sale on demand.	
SellInstruction	Define one or more conditions for the sale of bonds, if necessary for rebalancing or payment of liabilities. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. • **UpperBoundOperator**—The operator for the upper bound.	Enabled only if **SellAnyAsset** is **False**.

Name	Description	Condition
	• **UpperBound**—The upper bound for the characteristic. If you use the **CreditClassIndex** characteristic, the mappings to credit classes are as follows: • **0**—Govt • **1**—AAA • **2**—AA • **3**—A • **4**—BBB • **5**—BB • **6**—B • **7**—CCC • **8**—Default	
CustomOrdering	Select the variables and orders on which you want to order the on-demand sales. For each row, fill the following fields: • **OrderingVariable**—The variable to order on. Possible values: **Term**, **CreditClassIndex**, **Duration**, **Convexity**, **FairValueRedemptionYield**, **RelativeUnrealisedGain**, **BookReturn**. • **Order**—The order for the variable. Possible values: **HighestToLowest** or **LowestToHighest**. *For example*, to sell shortest-term bonds first, set **OrderingVariable** to **Term**, and **Order** to **LowestToHighest**.	
DefaultOrderingVariable	The preset variable that the software uses to order the sale of the assets.	
DefaultOrder	The order for the **DefaultOrderingVariable**.	

Outputs

Name	Description
BondsSold	The number of bonds sold over the time step. $\text{AssetsSold}_i(t) = \left\lceil \frac{\text{CashToBeRaised}_i}{\text{AssetPrice}_i^* \times (1 + \text{SaleCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rceil$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset • $\lceil x \rceil$ is the smallest integer greater than *x*.
ValueSold	The value of the bonds sold over the time step, in the currency of the managed portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.

Name	Description
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

BondBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A bond buy instruction defines which assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Defines a buy instruction. For each issuer, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the bond. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **NominalValue**—The nominal value of the bonds. • **CreditClass**—The credit class of the bonds to purchase. Characterizes the bond issuers, along with **CreditModel** and **EquityAsset**. • **CreditModel**—Select one of the existing credit models. Characterizes the bond issuers, along with **CreditClass** and **EquityAsset**. The CreditModel defines the economy of the issuer. • **EquityAsset**—Select an existing ParentEquityAsset or ParentEquityAssetCorrelationModel. Characterizes the bond issuers, along with **CreditClass** and **CreditModel**. • **Economy**—Defines the currency in which the bonds are issued, which can be different from the economy of the issuer. • **Type**—The type of bond. Select **Nominal** or **IndexLinked**. • **Term**—The term to maturity of the bonds. • **CouponDefinition**—Select **Fixed** or **Par**. • **Coupon**—The annual coupon rate of the bonds. • **Frequency**—The number of coupon payments per year. • **Seniority**—The seniority of the bonds. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02.	

Name	Description	Conditions
	• **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the purchased assets are currency hedged.	
PrincipalCashflowTarget	The cash account to which you want to direct maturity payments from the bonds.	
InterestCashflowTarget	The cash account to which you want to direct coupon payments from the bonds.	
DefaultCashflowTarget	The cash account to which you want to direct default payments from the bonds.	
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
BondsBought	Number of bonds bought, using this buy instruction, over this time step. $\mathrm{AssetsBought}_i(t) = \left\lfloor \frac{\mathrm{AmountToInvest}_i}{\mathrm{AssetPrice}_i^*(t) \times (1 + \mathrm{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to *x*.
ValueBought	Value of bonds bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\mathrm{TransactionCosts}(t) = \mathrm{AssetsBought}_i(t) \times \mathrm{AssetPrice}_i^*(t) \times \mathrm{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

EquitySellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An equity sell instruction defines the characteristics of equity assets that must be sold at each time step. In a single equity sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of equities, set up multiple EquitySellInstructions. In other words, for a logical AND, use a single equity sell instruction with multiple conditions. For a logical OR, use multiple equity sell instructions.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of equities. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **DividendYield**, **CapitalChange**, **CapitalIndex**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
SharesSold	Number of shares sold, using this sell instruction, over this time step.
ValueSold	Value of the shares sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

EquityOnDemandSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An on-demand equity sell instruction defines conditions for the sale of equities, if extra cash is required to support rebalancing or the payment of liabilities. The preset configuration is that any asset of this type in the portfolio is available for sale. You can change this configuration to define conditions of sale. In a single on-demand equity sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of equities, set up multiple EquityOnDemandSellInstructions. In other words, for a logical AND, use a single on-demand equity sell instruction with multiple conditions. For a logical OR, use multiple on-demand equity sell instructions.

Input variables

Name	Description	Condition
SellAnyAsset	Specify whether you want to make all assets available for sale on demand. Possible values: • **True**—Any asset is available for sale on demand. • **False**—Only the assets that you specify in **SellInstruction** are available for sale on demand.	
SellInstruction	Define one or more conditions for the sale of equities, if necessary for rebalancing or payment of liabilities. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **DividendYield**, **CapitalChange**, **CapitalIndex**, **RelativeUnrealisedGain**, **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.	Enabled only if **SellAnyAsset** is **False**.
CustomOrdering	Select the variables and orders on which you want to order the on-demand sales. For each row, fill the following fields: • **OrderingVariable**—The variable to order on. Possible values: **DividendYield, CapitalChange, BookReturn**. • **Order**—The order for the variable. Possible values: **HighestToLowest** or **LowestToHighest**.	
DefaultOrderingVariable	The preset variable that the software uses to order the sale of the assets.	
DefaultOrder	The order for the **DefaultOrderingVariable**.	

Outputs

Name	Description
SharesSold	Number of shares sold, using this sell instruction, over this time step. $\text{AssetsSold}_i(t) = \left[\frac{\text{CashToBeRaised}_i}{\text{AssetPrice}_i^* \times (1 + \text{SaleCost}_i)} \times \frac{X_a(t)}{X_p(t)}\right]$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy

Name	Description
	• $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset • $\lceil x \rceil$ is the smallest integer greater than x.
ValueSold	Value of the shares sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

EquityBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An equity buy instruction defines which equity assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Defines the equity assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the equity asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **EquityAsset**—The equity asset purchased. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the purchased assets are currency hedged.	
IncomeCashflowTarget	The cash account to which you want to direct regular income payments from the equity assets.	

Name	Description	Conditions
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
SharesBought	Number of shares bought, using this buy instruction, over this time step. $\text{AssetsBought}_i(t) = \left\lfloor \frac{\text{AmountToInvest}_i}{\text{AssetPrice}_i^*(t) \times (1 + \text{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to x.
ValueBought	Value of the shares bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\text{TransactionCosts}(t) = \text{AssetsBought}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

FundSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A fund sell instruction defines the characteristics of funds that must be sold at each time step. In a single fund sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of funds, set up multiple FundSellInstructions. In other words, for a logical AND, use a single fund sell instruction with multiple conditions. For a logical OR, use multiple fund sell instructions.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of funds. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **Price**, **TotalReturn**, **ReleativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

FundOnDemandSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An on-demand fund sell instruction defines conditions for the sale of funds. The preset configuration is that any asset of this type in the portfolio is available for sale. You can change this configuration to define conditions of sale. In a single on-demand fund sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of funds, set up multiple FundOnDemandSellInstructions. In other words, for a logical AND, use a single on-demand fund sell instruction with multiple conditions. For a logical OR, use multiple on-demand fund sell instructions.

Input variables

Name	Description	Condition
SellAnyAsset	Specify whether you want to make all assets available for sale on demand. Possible values: • **True**—Any asset is available for sale on demand. • **False**—Only the assets that you specify in **SellInstruction** are available for sale on demand.	
SellInstruction	Define one or more conditions for the sale of funds, if necessary for rebalancing or payment of liabilities. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **Price**, **TotalReturn**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.	Enabled only if **SellAnyAsset** is **False**.
CustomOrdering	Select the variables and orders on which you want to order the on-demand sales. For each row, fill the following fields: • **OrderingVariable**—The variable to order on. Possible values: **TotalReturn**, **RelativeUnrealisedGain**, or **BookReturn**. • **Order**—The order for the variable. Possible values: **HighestToLowest** or **LowestToHighest**.	
DefaultOrderingVariable	The preset variable that the software uses to order the sale of the assets.	
DefaultOrder	The order for the **DefaultOrderingVariable**.	

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step. $\mathrm{AssetsSold}_i(t) = \left\lceil \frac{\mathrm{CashToBeRaised}_i}{\mathrm{AssetPrice}_i^* \times (1 + \mathrm{SaleCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rceil$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset • $\lceil x \rceil$ is the smallest integer greater than x.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.

Name	Description
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

FundBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A fund buy instruction defines which fund assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Define the fund assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **FundAsset**—The fund asset purchased. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02.	
IncomeCashflowTarget	The cash account to which you want to direct income from the funds.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
UnitsBought	Number of units bought, using this buy instruction, over this time step. $\text{AssetsBought}_i(t) = \left\lfloor \frac{\text{AmountToInvest}_i}{\text{AssetPrice}_i^*(t) \times (1 + \text{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to x.
ValueBought	Value of the units bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\text{TransactionCosts}(t) = \text{AssetsBought}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

PropertySellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A property sell instruction defines the characteristics of property assets that must be sold at each time step.

Input variables

Name	Description
SellInstruction	Define one or more conditions for the sale of property assets. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound. • **Characteristic**—The characteristic which is checked for this condition. **EarningsYield**, **CapitalIndex**, **CapitalChange**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

PropertyOnDemandSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An on-demand property sell instruction defines conditions for the sale of property assets. The preset configuration is that any asset of this type in the portfolio is available for sale. You can change this configuration to define conditions of sale. In a single on-demand property sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of property assets, set up multiple PropertyOnDemandSellInstructions. In other words, for a logical AND, use a single on-demand property sell instruction with multiple conditions. For a logical OR, use multiple on-demand property sell instructions.

Input variables

Name	Description	Condition
SellAnyAsset	Specify whether you want to make all assets available for sale on demand. Possible values: • **True**—Any asset is available for sale on demand. • **False**—Only the assets that you specify in **SellInstruction** are available for sale on demand.	
SellInstruction	Define one or more conditions for the sale of property assets, if necessary for rebalancing or payment of liabilities. For each condition, fill the following fields: • **LowerBound**—The lower bound for the characteristic. • **LowerBoundOperator**—The operator for the lower bound.	Enabled only if **SellAnyAsset** is **False**.

Name	Description	Condition
	• **Characteristic**—The characteristic which is checked for this condition. **EarningsYield**, **CapitalIndex**, **CapitalChange**, **RelativeUnrealisedGain**, or **BookReturn**. • **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.	
CustomOrdering	Select the variables and orders on which you want to order the on-demand sales. For each row, fill the following fields: • **OrderingVariable**—The variable to order on. Possible values: **EarningsYield**, **CapitalChange**, **RelativeUnrealisedGain**, **BookReturn.** • **Order**—The order for the variable. Possible values: **HighestToLowest** or **LowestToHighest**.	
DefaultOrderingVariable	The preset variable that the software uses to order the sale of the assets.	
DefaultOrder	The order for the **DefaultOrderingVariable**.	

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step. $\text{AssetsSold}_i(t) = \left\lceil \frac{\text{CashToBeRaised}_i}{\text{AssetPrice}_i^* \times (1 + \text{SaleCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rceil$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset • $\lceil x \rceil$ is the smallest integer greater than *x*.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

PropertyBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A property buy instruction defines which property assets to buy as the projection progresses.

Input variables

Name	Description	Conditions
BuyInstruction	Define the property assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **PropertyAsset**—The property asset purchased. • **UnitSize**—Defines the time zero purchase price of a single unit of this asset, in the currency of the asset. This value increases in line with the property index as the projection progresses. • **AccountingConvention**—The accounting convention for the assets that are purchased. For more information about accounting conventions, see AccountingConventions. • **SmoothingMeanAge**—The intended mean age (in years) of the data weightings for the smoothing functionality. This value must be greater than or equal to zero. A value of zero indicates no smoothing. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **CurrencyHedge**—Select whether the returns from the purchased assets are currency hedged.	
IncomeCashflowTarget	The cash account to which you want to direct regular income payments from the assets.	
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
UnitsBought	Number of units bought, using this buy instruction, over this time step. $$\text{AssetsBought}_i(t) = \left\lfloor \frac{\text{AmountToInvest}_i}{\text{AssetPrice}_i^*(t) \times (1 + \text{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to x.
ValueBought	Value of the units bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\text{TransactionCosts}(t) = \text{AssetsBought}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

MBSSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An MBS sell instruction defines the characteristics of mortgage-backed securities that must be sold at each time step. In a single MBS sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of MBS, set up multiple MBSSellInstructions. In other words, for a logical AND, use a single MBS sell instruction with multiple conditions. For a logical OR, use multiple MBS sell instructions.

Input variables

Name	Description

SellInstruction	Define one or more conditions for the sale of mortgage-backed securities. For each condition, fill the following fields:
	• **LowerBound**—The lower bound for the characteristic.
	• **LowerBoundOperator**—The operator for the lower bound.
	• **Characteristic**—The characteristic which is checked for this condition. Select one of the following options:
	  ◦ **PricePerUnitBalance**—The Value/Balance ratio.
	  ◦ **MtgeTerm**—The remaining term.

Name	Description
	• **UpperBoundOperator**—The operator for the upper bound. • **UpperBound**—The upper bound for the characteristic.

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $\text{TransactionCosts}(t) = \text{AssetsSold}_i(t) \times \text{AssetPrice}_i^*(t) \times \text{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

MBSOnDemandSellInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An on-demand MBS sell instruction defines conditions for the sale of MBS assets. The preset configuration is that any asset of this type in the portfolio is available for sale. You can change this configuration to define conditions of sale. In a single on-demand MBS sell instruction, you can define multiple conditions, and the assets that satisfy *all* conditions are sold. If you want multiple conditions, where satisfying *any* one of the conditions results in the sale of MBS assets, set up multiple MBSOnDemandSellInstructions. In other words, for a logical AND, use a single on-demand MBS sell instruction with multiple conditions. For a logical OR, use multiple on-demand MBS sell instructions.

Input variables

Name	Description	Condition
SellAnyAsset	Specify whether you want to make all assets available for sale on demand. Possible values: • **True**—Any asset is available for sale on demand. • **False**—Only the assets that you specify in **SellInstruction** are available for sale on demand.	

Name	Description	Condition

SellInstruction	Define one or more conditions for the sale of mortgage-backed securities, if necessary for rebalancing or payment of liabilities. For each condition, fill the following fields:
	• **LowerBound**—The lower bound for the characteristic.
	• **LowerBoundOperator**—The operator for the lower bound.
	• **Characteristic**—The characteristic which is checked for this condition. Select one of the following options:
	  ◦ **PricePerUnitBalance**—The Value/Balance ratio.
	  ◦ **MtgeTerm**—The remaining term.
	• **UpperBoundOperator**—The operator for the upper bound.
	• **UpperBound**—The upper bound for the characteristic.
		Enabled only if **SellAnyAsset** is **False**.

CustomOrdering	Select the variables and orders on which you want to order the on-demand sales. For each row, fill the following fields: • **OrderingVariable**—The variable to order on. Possible values: **MtgeTerm**, **MBSCoupon**, or **BookReturn**. • **Order**—The order for the variable. Possible values: **HighestToLowest** or **LowestToHighest**.	
DefaultOrderingVariable	The preset variable that the software uses to order the sale of the assets.	
DefaultOrder	The order for the **DefaultOrderingVariable**.	

Outputs

Name	Description
UnitsSold	Number of units sold, using this sell instruction, over this time step. $$\mathrm{AssetsSold}_i(t) = \left\lceil \frac{\mathrm{CashToBeRaised}_i}{\mathrm{AssetPrice}_i^* \times (1 + \mathrm{SaleCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rceil$$ where: • $\mathrm{AssetPrice}_i^* = \mathrm{UnitBalance}_i \times \mathrm{MBSValue}_i^*(t)$ • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset • $\lceil x \rceil$ is the smallest integer greater than x.
ValueSold	Value of the units sold, using this sell instruction, over this time step, in the currency of the portfolio.
GainsRealised	Absolute measure of gains realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
LossesRealised	Absolute measure of losses realized at each time step, through sales related to this instruction. Reported in the currency of the managed portfolio.
TransactionCosts	The aggregate amount paid out in sale costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\mathrm{TransactionCosts}(t) = \mathrm{AssetsSold}_i(t) \times \mathrm{AssetPrice}_i^*(t) \times \mathrm{SaleCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy.

Name	Description
	• $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

MBSBuyInstruction

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

An MBS buy instruction defines which mortgage-backed security assets to buy as the projection progresses. MBS holdings pay out cash flows (interest, principal, prepayment, and refinancing) as they occur with the same frequency as the time step of the simulation.

Input variables

Name	Description	Conditions
BuyInstruction	Defines the mortgage-backed security assets to buy throughout the projection period. For each asset, fill the following fields: • **Proportion**—The proportion of the cash account to use to purchase the MBS asset. If the sum of proportions across all buy instructions in a time step is greater than 1, the proportions are scaled so that they sum to 1. • **UnitBalance**—The balance of the underlying mortgages per unit bought, in the currency of the asset. • **Issuer**—The issuer of the MBS asset purchased. • **MtgeTerm**—The remaining term of the mortgages in the underlying mortgage pool. • **Age**—The weighted average age, in months, of the mortgages at the time that the buy instruction executes. • **OASMtge**—The option adjusted spread of the mortgages. • **CouponDefinition**—The coupon type of the MBS assets. Select from the following options: ◦ **Fixed**—Purchase MBS assets with fixed coupons. ◦ **PrevailingRate**—Purchase MBS assets with fixed coupons implied by the prevailing rate at the time of buying, plus any spread. • **MtgeCoupon**—If **CouponDefinition** is **Fixed**, the bought MBS asset is initialized with the value in **MtgeCoupon**. If **CouponDefinition** is **PrevailingRate**, **MtgeCoupon** is the spread, in basis points, above the prevailing risk-free rate. • **MBSCoupon**—If **CouponDefinition** is **Fixed**, the bought MBS asset is initialized with the value in **MBSCoupon**. If **CouponDefinition** is **PrevailingRate**, **MBSCoupon** is the spread, in basis points, above the prevailing risk-free rate. • **PrevailingSpotRateTerm**—The term used to infer the prevailing risk-free spot rate. • **SaleCost**—The proportional transaction cost on the sale of this asset. *For example*, to set a 2% transaction cost, enter 0.02. • **PurchaseCost**—The proportional transaction cost on the purchase of this asset. *For example*, to set a 2% transaction cost, enter 0.02.	

Name	Description	Conditions
	• **CurrencyHedge**—Select whether the returns from the purchased assets are currency hedged.	
InterestCashflowTarget	The cash account to which you want to direct regular income from the assets.	
PrincipalCashflowTarget	The cash account to which you want to direct principal payments from the assets.	
PrepaymentCashflowTarget	The cash account to which you want to direct cash flows from prepayment from the assets.	
RefinancingCashflowTarget	The cash account to which you want to direct cash flows from refinancing from the assets.	
CurrencyHedgeIncomeTarget	The cash account to which you want to direct payments from the currency hedging contracts.	
ApplyConditions	To use this buy instruction only when certain economic conditions are met or not met, select **True**. To always use this buy instruction, select **False**.	
Conditions	Select the TradingCondition that you want to apply to this buy instruction. For more information about creating trading conditions, see TradingCondition.	Enabled only if **ApplyConditions** is **True**.
Operator	Defines when to use the buy instruction: • **ConditionsMet**—Use the instruction when the **Conditions** are met. • **ConditionsNotMet**—Use the instruction when the **Conditions** are not met.	Enabled only if **ApplyConditions** is **True**.

Outputs

Name	Description
UnitsBought	Number of MBS assets bought, using this buy instruction, over this time step, in the currency of the portfolio. $$\mathrm{AssetsBought}_i(t) = \left\lfloor \frac{\mathrm{AmountToInvest}_i}{\mathrm{AssetPrice}_i^*(t) \times (1 + \mathrm{PurchaseCost}_i)} \times \frac{X_a(t)}{X_p(t)} \right\rfloor$$ where: • $\mathrm{AssetPrice}_i^*(t) = \mathrm{UnitBalance}_i \times \mathrm{MBSValue}_i^*(t)$ • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy. • $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset. • $\lfloor x \rfloor$ is the largest integer smaller than or equal to *x*. Any surplus amount is added to the cash account.
ValueBought	Value of the MBS assets bought, using this buy instruction, over this time step, in the currency of the portfolio.
TransactionCosts	The aggregate amount paid out in purchase costs over the time step, for assets sold using this instruction, in the currency of the portfolio. $$\mathrm{TransactionCosts}(t) = \mathrm{AssetsBought}_i(t) \times \mathrm{AssetPrice}_i^*(t) \times \mathrm{PurchaseCost}_i \times \frac{X_p(t)}{X_a(t)}$$ where: • $X_p(t)$ is the ExchangeRate.NominalValue of the portfolio economy.

Name	Description
	• $X_a(t)$ is the ExchangeRate.NominalValue of the economy of the asset.

Liabilities

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

You can add a liabilities model to model the liabilities for your managed portfolio group. Liabilities are paid as a priority, using available cash. If there is not enough cash in the group, then the software sells "on demand". Otherwise, payment of liabilities causes the group cash to go negative.

Addable submodels

Name	Description
LiabilityCashFlow	Defines a list of liability cash flows which share an economy and valuation basis.
LiabilityProcessor	Enables you to define the calculations for liability related outputs using a flexible framework.

Addable containers

Name	Description
VolatilityAdjustments	Container that holds the FundamentalSpread and VolatilityAdjustment models.

Outputs

Name	Description
CashFlow	Aggregate liability cash flow paid at this time step, in the currency of the group. $$\mathrm{CashFlow}(t) = X_G(t) \times \sum_i \frac{\mathrm{CashFlow}_i^*(t)}{X_{L_i}(t)}$$ where: • $X_G(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the managed portfolio group. • $X_{L_i}(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the liability cash flow *i*. • The summation is over all liability cash flow and liability processor models.

Name	Description
PresentValue	Present value of the aggregate expected cash flows on the valuation basis that you specify, in the currency of the group. $$\text{PresentValue}(t) = X_G(t) \times \sum_i \frac{\text{PresentValue}_i^*(t)}{X_{L_i}(t)}$$ where: • $X_G(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the managed portfolio group. • $X_{L_i}(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the liability cash flow *i*. • The summation is over all liability cash flow and liability processor models.
Duration	The duration of the liabilities within the Group. $$\text{Duration}(t) = \frac{X_G(t)}{\text{PresentValue}_G(t)} \times \sum_i \frac{\text{PresentValue}_i^*(t)}{X_{L_i}(t)} \times \text{Duration}_i(t)$$ where: • $X_G(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the managed portfolio group. • $X_{L_i}(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the liability cash flow *i*. • $\text{PresentValue}_G(t)$ is the present value at time t, of the total Group liabilities. • $\text{PresentValue}_i(t)$ is the present value at time t, of the liability cash flow *i*. • $\text{Duration}_i(t)$ is the duration at time t, of the liability cash flow *i*. • The summation is over all liability cash flow and liability processor models.
Convexity	The convexity of the liabilities within the Group. $$\text{Convexity}(t) = \frac{X_G(t)}{\text{PresentValue}_G(t)} \times \sum_i \frac{\text{PresentValue}_i^*(t)}{X_{L_i}(t)} \times \text{Convexity}_i(t)$$ where: • $X_G(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the managed portfolio group. • $X_{L_i}(t)$ is the exchange rate (ExchangeRate.NominalValue) at time *t* from the economy of the liability cash flow *i*. • $\text{PresentValue}_G(t)$ is the present value at time t, of the total Group liabilities. • $\text{PresentValue}_i(t)$ is the present value at time t, of the liability cash flow *i*. • $\text{Convexity}_i(t)$ is the convexity at time t, of the liability cash flow *i*. • The summation is over all liability cash flow and liability processor models.

LiabilityCashFlow

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines a vector of liability cash flows that share an economy and a valuation basis.

Input variables

Name	Description	Conditions
Economy	The economy for the cash flows.	
ValuationBasis	The valuation basis for the cash flows: • **RiskFree**—The software uses the primary nominal yield curve, from the economy you define in **Economy**, as the discount basis. • **RiskFreePlusVA**—The software applies the volatility adjustment calculated in the selected **VolatilityAdjustmentModel** to the **RiskFree** discount basis.	
VolatilityAdjustmentModel	Select the VolatilityAdjustment model that should be used when the **ValuationBasis** is set to **RiskFreePlusVA**.	Enabled only if **ValuationBasis** is **RiskFreePlusVA**.
CashFlows	Define the term of payment and respective payment to make for each modeled cash flow. Enter terms as annual (or part annual) points from the base date of the simulation.	

Outputs

Name	Description
CashFlow	Liability cash flow paid at this time step, in the currency of the economy for this model. $\mathrm{CashFlow}^*(t) = \sum_{\forall \mathrm{CashFlowTime}_i \in (t-\Delta t, t]} \mathrm{CashFlow}_i$ where the summation is over all cash flows from this liability model occurring since the previous time step, that is, for which $\mathrm{CashFlowTime}_i$ falls within the time interval $(t - \Delta t, t]$.
PresentValue	Present value of the expected cash flows on the valuation basis that you specify, in the currency of the economy for this model. The present value is defined as being the sum of the discounted future cash flows. At simulation time *t*, the present value when the **ValuationBasis** is set to **RiskFree** is: $\mathrm{PresentValue}^*(t) = \sum_i \mathrm{CashFlow}_i \times \mathrm{ZCBP}_L(\mathrm{Govt}, \mathrm{CashFlowTime}_i - t, 3, t)$ where $\mathrm{ZCBP}_L(\mathrm{CreditClass}, \mathrm{Term}, \mathrm{Seniority}, t)$ is the discount factor, being a risk-free zero coupon bond price from the primary nominal yield curve of the economy of the liability at simulation time *t*, and the summation is over all unexpired cash flows. If $t \geq \mathrm{CashFlowTime}_i$ for any cash flow, then the cash flow has expired and will have already been paid. If $t \geq \mathrm{CashFlowTime}_i$ for all cash flows then the present value is zero. When the **ValuationBasis** is set to **RiskFreePlusVA**, the selected volatility adjustment is added to the risk-free spot rate from the primary nominal yield curve of the economy, and then these rates are converted to zero coupon bond prices which are used in place of the $\mathrm{ZCBP}_L(\mathrm{CreditClass}, \mathrm{Term}, \mathrm{Seniority}, t)$ term in the calculation above. For more information about the **RiskFreePlusVA** calculation, see the VolatilityAdjustment section of the *Scenario Generator Managed Portfolios Methodology Guide*.

Name	Description
Duration	The duration of the liability cash flow. At simulation time t, the duration when the **ValuationBasis** is set to **RiskFree** is: $$\mathrm{Duration}(t) = \frac{\Sigma_i (\mathrm{CashFlowTime}_i - t) \times \mathrm{CashFlow}_i \times \mathrm{ZCBP}_L(\mathrm{Govt}, \mathrm{CashFlowTime}_i - t, 3, t)}{\Sigma_i \mathrm{CashFlow}_i \times \mathrm{ZCBP}_L(\mathrm{Govt}, \mathrm{CashFlowTime}_i - t, 3, t)}$$ where $\mathrm{ZCBP}_L(\mathrm{CreditClass}, \mathrm{Term}, \mathrm{Seniority}, t)$ is the discount factor, being a risk-free zero coupon bond price from the primary nominal yield curve of the economy of the liability at simulation time t, and the summation is over all unexpired cash flows. When the **ValuationBasis** is set to **RiskFreePlusVA**, the selected volatility adjustment is added to the risk-free spot rate from the primary nominal yield curve of the economy, and then these rates are converted to zero coupon bond prices which are used in place of the $\mathrm{ZCBP}_L(\mathrm{CreditClass}, \mathrm{Term}, \mathrm{Seniority}, t)$ term in the calculation above.
Convexity	The convexity of the liability cash flow. At simulation time t, the convexity when the **ValuationBasis** is set to **RiskFree** is: $$\mathrm{Convexity}(t) = \frac{\Sigma_i (\mathrm{CashFlowTime}_i - t)^2 \times \mathrm{CashFlow}_i \times \mathrm{ZCBP}_L(\mathrm{Govt}, \mathrm{CashFlowTime}_i - t, 3, t)}{\Sigma_i \mathrm{CashFlow}_i \times \mathrm{ZCBP}_L(\mathrm{Govt}, \mathrm{CashFlowTime}_i - t, 3, t)}$$ where $\mathrm{ZCBP}_L(\mathrm{CreditClass}, \mathrm{Term}, \mathrm{Seniority}, t)$ is the discount factor, being a risk-free zero coupon bond price from the primary nominal yield curve of the economy of the liability at simulation time t, and the summation is over all unexpired cash flows. When the **ValuationBasis** is set to **RiskFreePlusVA**, the selected volatility adjustment is added to the risk-free spot rate from the primary nominal yield curve of the economy, and then these rates are converted to zero coupon bond prices which are used in place of the $\mathrm{ZCBP}_L(\mathrm{CreditClass}, \mathrm{Term}, \mathrm{Seniority}, t)$ term in the calculation above.

LiabilityProcessor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The liability processor node enables you to define the calculations for liability related outputs using a flexible framework. For more information about how to use processors, see the Processors user guide section. A liability processor example can be found at *%programdata%\Moody's Analytics\SG\<version>\Data\LiabilityProcessors*. To add this example to your simulation file, under the liabilities node, you can use the **Add > Existing** option.

Warning! Whilst it is possible to select liability cash flow and other liability processor model outputs as inputs to a liability processor within the user interface, this should not be attempted as it may cause errors.

Submodels

Name	Description
Calculations	A container for addable processors, which you can use to define calculations for expected and realized liability cash flows and discount curves.
PresentValue	Defines the present value of the liabilities specified in this processor container, using a discount curve calculation processor (specified as zero coupon bond prices) and an expected cash flow calculation processor that you select. This value contributes to the overall Liabilities present value output.

Addable submodels

Name	Description
Processor	Processor model in which you can define additional liability output calculations.
DiscountValue	Defines additional present values for the liabilities specified in this processor container, using a discount curve calculation processor - specified as zero coupon bond prices - and an expected cash flow calculation processor that you select.

Input variables

Name	Description
Cashflow	Select the processor model to use for the realized liability cash flow.
SCRBaseValue	Select the processor output to use for the base value of these liabilities in the InterestRateSCR calculation.
SCRInterestUpValue	Select the processor output to use for the UpStress value of these liabilities in the InterestRateSCR calculation.
SCRInterestDownValue	Select the processor output to use for the DownStress value of these liabilities in the InterestRateSCR calculation.
Global Vectors	Specify the table of vector constants available to processors in this collection. Fill the following fields: • **Term**—The term at which any cash flow value applies. • **Vector1**–**Vector5**—Values which may be used to calculate liability cash flows and present values.
Global Variables	Global variables are software outputs that you can use in all processors under this node.
Global Constants	Global constants are constant values that you can use in all processors under this node.
PreT0LagBehaviour	Defines how the software handles output lags that result in a pre-time zero output. Select one of the following options: • **0**—Output a zero for all pre-time step zero outputs. • **NaN**—Output a NaN for all pre-time step zero outputs. • **UseT0Value**—For pre-time step zero outputs, use the time zero value. You cannot use this option if you use self-referencing in any processors. *For example*, if you have a variable with a lag of 4, and you select **0** for the **PreT0LagBehaviour**, the value for that variable that the software uses in the calculation at time 0, 1, 2, and 3 is 0.
Economy	Select the economy of the liability outputs within this processor collection.

Outputs

Name	Description
CashFlow	The realized cash flow of the liabilities defined within this processor container.
PresentValue	$\text{PresentValue}(t) = \sum_{rows} \text{DiscountCurve}(t) \times \text{Cashflows}(t)$ Where **DiscountCurve** and **Cashflows** are those that you specify in PresentValue.
SCRBaseValue	The value used in the calculation of BaseNAV for the InterestRateSCR calculation, for the liabilities defined within this processor container.

Name	Description
SCRInterestUpValue	The value used in the calculation of StressUpNAV for the InterestRateSCR calculation, for the liabilities defined within this processor container.
SCRInterestDownValue	The value used in the calculation of StressDownNAV for the InterestRateSCR calculation, for the liabilities defined within this processor container.

Calculations

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A container for calculation processors. You can add more processor models under this node to define calculations for the liability outputs.

Submodels

Name	Description
RemainingTerm	Calculation processor containing a calculation example for the term remaining between the current time step of the projection and the time of liability payment, where the initial term is defined in the term column under GlobalVectors.
Cashflow	Calculation processor containing a calculation example for the realized cash flow over each time step of the projection, where the initial term and cash flow are defined in the term and vector1 columns respectively, under GlobalVectors.

Addable submodels

Name	Description
Processor	Defines a single calculation.

RemainingTerm

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This processor shows a calculation example for the term remaining between the current time step of the projection and the time of liability payment, where the initial term is defined in the term column under GlobalVectors. This processor may be used as part of a calculation in another processor, *for example*, it might be used in a calculation to define term specific zero coupon bond prices for discounting cash flows.

The remaining term model has the **Calculation** parameter preset as **Max(*term* - *t*(),0)**. You can amend this parameter if needed.

Input variables

Name	Description
LinkedProcessors	Select the processors that you want to use as variables in this processor. For each processor, fill the following values: • **Name**—A name for the variable. For naming constraints, see the Processors user guide section. • **Output**—The processor to use for this variable.
Variables	Local variables for this calculation. For each variable, fill the following values: • **Name**—A name for the variable. For variable naming constraints, see the Processors user guide section. • **Output**—The output to use for this variable. • **Lag**—To use the output value from a previous time step, enter the number of time steps to go back. *For example*, if you enter 2, the software uses the time step three value for the output at time step five. • **ParameterIndex**—If **Output** has a choice of parameters, *for example*, SpotRate(Govt,1,3), you can override one of the parameters by specifying its index here. *For example*, to override the second parameter, enter **2** as the index. • **OverrideVariable**—The variable that you want to use to override the parameter specified in **ParameterIndex**.
Calculation	The calculation that you want to perform. For more information about the calculation format, see the Processors user guide section.
UseGlobalVectors	Select whether you want to use global vector constants in this processor.

Outputs

Name	Description
Value [Row]	The value of the processor, based on the calculation that you define, at the specified row.
Sum	The sum of the calculated values.

Cashflow

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This processor shows a calculation example for the realized cash flow over each time step of the projection, where the initial term and cash flow are defined in the term and vector1 columns respectively, under GlobalVectors. This processor might be altered or used in conjunction with a calculation in another processor, *for example*, the vector1 part of the calculation could be adjusted to refer to an expected cash flow processor variable.

The remaining term model has the **Calculation** parameter preset as **if(*t*()-dt()<Term&Term<=t(),vector1,0)**.

Input variables

Name	Description
LinkedProcessors	Select the processors that you want to use as variables in this processor. For each processor, fill the following values: • **Name**—A name for the variable. For naming constraints, see the Processors user guide section. • **Output**—The processor to use for this variable.
Variables	Local variables for this calculation. For each variable, fill the following values: • **Name**—A name for the variable. For variable naming constraints, see the Processors user guide section. • **Output**—The output to use for this variable. • **Lag**—To use the output value from a previous time step, enter the number of time steps to go back. *For example*, if you enter 2, the software uses the time step three value for the output at time step five. • **ParameterIndex**—If **Output** has a choice of parameters, *for example*, SpotRate(Govt,1,3), you can override one of the parameters by specifying its index here. *For example*, to override the second parameter, enter **2** as the index. • **OverrideVariable**—The variable that you want to use to override the parameter specified in **ParameterIndex**.
Calculation	The calculation that you want to perform. For more information about the calculation format, see the Processors user guide section.
UseGlobalVectors	Select whether you want to use global vector constants in this processor.

Outputs

Name	Description
Value [Row]	The value of the processor, based on the calculation that you define, at the specified row.
Sum	The sum of the calculated values.

Processor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A processor model can be added for any additional calculations that you want to perform, *for example*, to define how expected cashflows evolve over the course of the projection. For more information about the operators and functions available to processors, see the Processors user guide section.

Input variables

Name	Description
LinkedProcessors	Select the processors that you want to use as variables in this processor. For each processor, fill the following values: • **Name**—A name for the variable. For naming constraints, see the Processors user guide section. • **Output**—The processor to use for this variable.
Variables	Local variables for this calculation. For each variable, fill the following values: • **Name**—A name for the variable. For variable naming constraints, see the Processors user guide section. • **Output**—The output to use for this variable. • **Lag**—To use the output value from a previous time step, enter the number of time steps to go back. *For example*, if you enter 2, the software uses the time step three value for the output at time step five. • **ParameterIndex**—If **Output** has a choice of parameters, *for example*, SpotRate(Govt,1,3), you can override one of the parameters by specifying its index here. *For example*, to override the second parameter, enter **2** as the index. • **OverrideVariable**—The variable that you want to use to override the parameter specified in **ParameterIndex**.
Calculation	The calculation that you want to perform. For more information about the calculation format, see the Processors user guide section.
UseGlobalVectors	Select whether you want to use global vector constants in this processor.

Outputs

Name	Description
Value [Row]	The value of the processor, based on the calculation that you define, at the specified row.
Sum	The sum of the calculated values.

PresentValue

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines the present value of the liabilities specified in this processor container, using a discount curve calculation processor - specified as zero coupon bond prices - and an expected cash flow calculation processor that you select. This output from this model contributes to the overall Liabilities present value output.

Input variables

Name	Description
DiscountCurve	Select the processor model to use as the discount curve.

Name	Description
Cashflows	Select the processor model to use for the expected cash flows.
Term	Select the processor model to use for the term of the expected cash flows in duration and convexity calculations.

Outputs

Name	Description
Value	The present value of the cash flows. $\text{Value}(t) = \sum_i \text{DiscountCurve}_i(t) \times \text{Cashflows}_i(t)$ where *i* represents the rows in the specified Cashflows and DiscountCurve vectors.
Duration	The duration of the cash flows. $\text{Duration}(t) = \frac{\sum_i \text{Term}_i \times \text{Cashflows}_i \times \text{DiscountCurve}_i}{\sum_i \text{Cashflows}_i \times \text{DiscountCurve}_i}$ where *i* represents the rows in the specified Term, Cashflows, and DiscountCurve vectors.
Convexity	The convexity of the cash flows. $\text{Convexity}(t) = \frac{\sum_i (\text{Term}_i)^2 \times \text{Cashflows}_i \times \text{DiscountCurve}_i}{\sum_i \text{Cashflows}_i \times \text{DiscountCurve}_i}$ where *i* represents the rows in the specified Term, Cashflows, and DiscountCurve vectors.

DiscountValue

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Defines additional present values for the liabilities specified in this processor container, using a discount curve calculation processor - specified as zero coupon bond prices - and an expected cash flow calculation processor that you select.

Input variables

Name	Description
DiscountCurve	Select the processor model to use as the discount curve.
Cashflows	Select the processor model to use for the expected cash flows.
Term	Select the processor model to use for the term of the expected cash flows in duration and convexity calculations.

Outputs

Name	Description
Value	The present value of the cash flows. $$\text{Value}(t) = \sum_i \text{DiscountCurve}_i(t) \times \text{Cashflows}_i(t)$$ where *i* represents the rows in the specified Cashflows and DiscountCurve vectors.
Duration	The duration of the cash flows. $$\text{Duration}(t) = \frac{\sum_i \text{Term}_i \times \text{Cashflows}_i \times \text{DiscountCurve}_i}{\sum_i \text{Cashflows}_i \times \text{DiscountCurve}_i}$$ where *i* represents the rows in the specified Term, Cashflows, and DiscountCurve vectors.
Convexity	The convexity of the cash flows. $$\text{Convexity}(t) = \frac{\sum_i (\text{Term}_i)^2 \times \text{Cashflows}_i \times \text{DiscountCurve}_i}{\sum_i \text{Cashflows}_i \times \text{DiscountCurve}_i}$$ where *i* represents the rows in the specified Term, Cashflows, and DiscountCurve vectors.

Processor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Set up a processor for any additional calculations that you want to perform. For more information about the operators and functions available to processors, see the Processors user guide section.

Input variables

Name	Description
LinkedProcessors	Select the processors that you want to use as variables in this processor. For each processor, fill the following values: • **Name**—A name for the variable. For naming constraints, see the Processors user guide section. • **Output**—The processor to use for this variable.
Variables	Local variables for this calculation. For each variable, fill the following values: • **Name**—A name for the variable. For variable naming constraints, see the Processors user guide section. • **Output**—The output to use for this variable. • **Lag**—To use the output value from a previous time step, enter the number of time steps to go back. *For example*, if you enter 2, the software uses the time step three value for the output at time step five. • **ParameterIndex**—If **Output** has a choice of parameters, *for example*, SpotRate(Govt,1,3), you can override one of the parameters by specifying its index here. *For example*, to override the second parameter, enter **2** as the index.

Name	Description
	• **OverrideVariable**—The variable that you want to use to override the parameter specified in **ParameterIndex**.
Calculation	The calculation that you want to perform. For more information about the calculation format, see the Processors user guide section.
UseGlobalVectors	Select whether you want to use global vector constants in this processor.

Outputs

Name	Description
Value [Row]	The value of the processor, based on the calculation that you define, at the specified row.
Sum	The sum of the calculated values.

VolatilityAdjustments

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Container that holds the FundamentalSpread and VolatilityAdjustment models.

Addable submodels

Name	Description
FundamentalSpread	This model contains the economy-specific parameters that you require to calculate the fundamental spread.
VolatilityAdjustment	This model enables you to project an estimate of the volatility adjustment defined by EIOPA's requirements.

FundamentalSpread

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Contains the economy-specific parameters required to calculate the fundamental spread.

Input variables

Name	Description
Economy	The Economy relevant for the LTAS, PD, and CoD parameters specified in this submodel.
GovtLTAS	The Government LTAS values for each maturity relevant for this economy. All values should be specified as percentages. *For example*, 0.5% should be entered as 0.5.

Name	Description
CorpFinancialLTAS	The Corporate LTAS values for each maturity and credit step, relevant for instruments classed as financial in this economy. All values should be specified as percentages. *For example*, 0.5% should be entered as 0.5.
CorpNonFinancialLTAS	The Corporate LTAS values for each maturity and credit step, relevant for instruments classed as non-financial in this economy. All values should be specified as percentages. *For example*, 0.5% should be entered as 0.5.
FinancialPD	The probability of default values for each maturity and credit step, relevant for instruments classed as financial in this economy. All values should be specified as percentages. *For example*, 0.5% should be entered as 0.5.
NonFinancialPD	The probability of default values for each maturity and credit step, relevant for instruments classed as non-financial in this economy. All values should be specified as percentages. *For example*, 0.5% should be entered as 0.5.
FinancialCoD	The cost of downgrade values for each maturity and credit step, relevant for instruments classed as financial in this economy. All values should be specified as percentages. *For example*, 0.5% should be entered as 0.5.
NonFinancialCoD	The cost of downgrade values for each maturity and credit step, relevant for instruments classed as non-financial in this economy. All values should be specified as percentages. *For example*, 0.5% should be entered as 0.5.

VolatilityAdjustment

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Enables you to project an estimate of the volatility adjustment calculation defined by EIOPA's requirements.

Submodels

Name	Description
CurrencyVA	The currency volatility adjustment.

Addable submodels

Name	Description
CountryVA	The country volatility adjustment.

Input variables

Name	Description
VAScalar	Scalar applied in the total volatility adjustment calculation.
AddOn	The value, specified in basis points, that should be added to the total volatility adjustment.

Outputs

Name	Description
VolatilityAdjustment	The total volatility adjustment, including any country specific increase. For more information about this calculation, see the *Scenario Generator Managed Portfolios Methodology Guide*.
SpotRate [YieldCurve, CreditClass, Maturity, Seniority]	The spot rate including volatility adjustment for the specified base yield curve at the specified maturity. $\mathrm{SpotRate}(\mathrm{YCModel}, \mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority})(t) =$ $\mathrm{YCModel.\,SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) + \mathrm{VolatilityAdjustment}(t)$ where the $\mathrm{YCModel}$ is the selected yield curve model (real or nominal) from the Economies node.
ZCBP [YieldCurve, CreditClass, Maturity, Seniority]	The zero coupon bond price including volatility adjustment for the specified base yield curve at the specified maturity. $\mathrm{ZCBP}(\mathrm{YCModel}, \mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority})(t) =$ $(1 + \mathrm{YCModel.\,SpotRate}(\mathrm{CreditClass}, \mathrm{Maturity}, \mathrm{Seniority}, t) + \mathrm{VolatilityAdjustment}(t))^{-Maturity}$ where the $\mathrm{YCModel}$ is the selected yield curve model (real or nominal) from the Economies node.

CurrencyVA

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The currency volatility adjustment.

Submodels

Name	Description
GovtReferencePortfolio	The government reference portfolio.
CorpReferencePortfolio	The corporate reference portfolio.

Input variables

Name	Description
CentralGovtAssets	The weight to apply to the spread calculated from the assets specified in the GovtReferencePortfolio parameter set.
CorporateAssets	The weight to apply to the spread calculated from the assets specified in the CorpReferencePortfolio parameter set.

Outputs

Name	Description
Spread	The spread applied in the calculation of the currency volatility adjustment. It is the difference between the effective interest rate derived from the reference portfolio and the risk-free interest rate term structure. $\mathrm{Spread}(t) = \mathrm{CentralGovtAssets} \times \mathrm{Spread}_{Govt}(t) + \mathrm{CorporateAssets} \times \mathrm{Spread}_{Corp}(t)$ where: • $\mathrm{CentralGovtAssets}$ is the value specified in the $\mathrm{CentralGovtAssets}$ parameter of this CurrencyVolatilityAdjustment model. • $\mathrm{Spread}_{Govt}(t)$ is the Spread output on the GovtReferencePortfolio submodel of this CurrencyVolatilityAdjustment model, at time step t. • $\mathrm{CorporateAssets}$ is the value specified in the $\mathrm{CorporateAssets}$ parameter of this CurrencyVolatilityAdjustment model. • $\mathrm{Spread}_{Corp}(t)$ is the Spread output on the CorpReferencePortfolio submodel of this CurrencyVolatilityAdjustment model, at time step t.
RiskCorrection	The risk correction applied in the calculation of the currency volatility adjustment. It is the portion of the spread that is attributed as the fundamental spread. $\mathrm{RiskCorrection}(t) = \mathrm{CentralGovtAssets} \times \mathrm{RiskCorrection}_{Govt}(t) + \mathrm{CorporateAssets} \times \mathrm{RiskCorrection}_{Corp}(t)$ where: • $\mathrm{CentralGovtAssets}$ is the value specified in the $\mathrm{CentralGovtAssets}$ parameter of this CurrencyVolatilityAdjustment model. • $\mathrm{RiskCorrection}_{Govt}(t)$ is the RiskCorrection output on the GovtReferencePortfolio submodel of this CurrencyVolatilityAdjustment model, at time step t. • $\mathrm{CorporateAssets}$ is the value specified in the $\mathrm{CorporateAssets}$ parameter of this CurrencyVolatilityAdjustment model. • $\mathrm{RiskCorrection}_{Corp}(t)$ is the RiskCorrection output on the CorpReferencePortfolio submodel of this CurrencyVolatilityAdjustment model, at time step t.
VolatilityAdjustment	The currency volatility adjustment, calculated from the Spread and RiskCorrection outputs described above. $\mathrm{VolatilityAdjustment}(t) = \mathrm{VAScalar} \times \{\mathrm{Spread}(t) - \mathrm{RiskCorrection}(t)\}$

GovtReferencePortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The government reference portfolio.

Input variables

Name	Description
ReferencePortfolio	Specifies the instruments that make up the Government Reference Portfolio. Fill the following fields: • **RelativeMarketValue**—The relative market value for each instrument in the Reference Portfolio. • **BasicRiskFreeModel**—The yield curve model that models EIOPA's risk free rate.

Name	Description
	• **AssetRiskFreeModel**—The relevant risk free yield curve model for each instrument in the Reference Portfolio. • **AssetCreditModel**—The relevant credit spread model for each instrument in the Reference Portfolio. • **CreditClass**—The credit class relevant to the credit model selected in AssetCreditModel. • **Duration**—The duration for each instrument in the Reference Portfolio.
RiskCorrection	In the calculation of the fundamental spread on government bonds, this value represents the risk correction expressed as a proportion of the long-term average spread (LTAS).

Outputs

Name	Description
Spread	The spread of the reference portfolio, relative to the risk free rate. It is expressed as the internal effective rate, based on the specified composition of instruments.
RiskCorrection	The risk correction for the reference portfolio, based on the specified composition of instruments. For each of the instruments within the reference portfolio, the risk correction is defined as the fundamental spread.

CorpReferencePortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The corporate reference portfolio.

Input variables

Name	Description
ReferencePortfolio	Specifies the instruments that make up the Corporate Reference Portfolio. Fill the following fields: • **RelativeMarketValue**—The relative market value for each instrument in the Reference Portfolio. • **Type**—The type of the instrument. Select **Financial** or **Non-Financial**. • **BasicRiskFreeModel**—The yield curve model that models EIOPA's risk free rate. • **AssetRiskFreeModel**—The relevant risk free yield curve model for each instrument in the Reference Portfolio. • **AssetCreditModel**—The relevant credit spread model for each instrument in the Reference Portfolio. • **CreditClass**—The credit class relevant to the credit model selected in AssetCreditModel. • **Duration**—The duration for each instrument in the Reference Portfolio.
RiskCorrection	In the calculation of the fundamental spread on corporate bonds, this value is the proportion of the long-term average spread (LTAS) applied in the risk correction.

Outputs

Name	Description
Spread	The spread of the reference portfolio, relative to the risk free rate. It is expressed as the internal effective rate, based on the specified composition of instruments.

Name	Description
RiskCorrection	The risk correction for the reference portfolio, based on the specified composition of instruments. For each of the instruments within the reference portfolio, the risk correction is defined as the fundamental spread.

CountryVA

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The country volatility adjustment.

Submodels

Name	Description
GovtReferencePortfolio	The government reference portfolio.
CorpReferencePortfolio	The corporate reference portfolio.

Input variables

Name	Description
CentralGovtAssets	The weight to apply to the spread calculated from the assets specified in the GovtReferencePortfolio parameter set.
CorporateAssets	The weight to apply to the spread calculated from the assets specified in the CorpReferencePortfolio parameter set.
Threshold	The value, specified in basis points, that the risk corrected country spread must exceed to contribute towards the total volatility adjustment calculation.

Outputs

Name	Description
Spread	The spread applied in the calculation of the country specific volatility adjustment. It is the difference between the effective interest rate derived from the country reference portfolio and the risk-free interest rate term structure. $\text{Spread}(t) = \text{CentralGovtAssets} \times \text{Spread}_{Govt}(t) + \text{CorporateAssets} \times \text{Spread}_{Corp}(t)$ where: • CentralGovtAssets is the value specified in the CentralGovtAssets parameter of this CountryVolatilityAdjustment model. • $\text{Spread}_{Govt}(t)$ is the Spread output on the GovtReferencePortfolio submodel of this CountryVolatilityAdjustment model, at time step t. • CorporateAssets is the value specified in the CorporateAssets parameter of this CountryVolatilityAdjustment model. • $\text{Spread}_{Corp}(t)$ is the Spread output on the CorpReferencePortfolio submodel of this CountryVolatilityAdjustment model, at time step t.

Name	Description
RiskCorrection	The risk correction applied in the calculation of the country specific volatility adjustment. It is the portion of the spread that is attributed as the fundamental spread. $\text{RiskCorrection}(t) = \text{CentralGovtAssets} \times \text{RiskCorrection}_{Govt}(t) + \text{CorporateAssets} \times \text{RiskCorrection}_{Corp}(t)$ where: • CentralGovtAssets is the value specified in the CentralGovtAssets parameter of this CountryVolatilityAdjustment model. • $\text{RiskCorrection}_{Govt}(t)$ is the RiskCorrection output on the GovtReferencePortfolio submodel of this CountryVolatilityAdjustment model, at time step t. • CorporateAssets is the value specified in the CorporateAssets parameter of this CountryVolatilityAdjustment model. • $\text{RiskCorrection}_{Corp}(t)$ is the RiskCorrection output on the CorpReferencePortfolio submodel of this CountryVolatilityAdjustment model, at time step t.
VolatilityAdjustment	The country specific volatility adjustment. For more information about this calculation, see the *Scenario Generator Managed Portfolios Methodology Guide*.

GovtReferencePortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The government reference portfolio.

Input variables

Name	Description
ReferencePortfolio	Specifies the instruments that make up the Government Reference Portfolio. Fill the following fields: • **RelativeMarketValue**—The relative market value for each instrument in the Reference Portfolio. • **BasicRiskFreeModel**—The yield curve model that models EIOPA's risk free rate. • **AssetRiskFreeModel**—The relevant risk free yield curve model for each instrument in the Reference Portfolio. • **AssetCreditModel**—The relevant credit spread model for each instrument in the Reference Portfolio. • **CreditClass**—The credit class relevant to the credit model selected in AssetCreditModel. • **Duration**—The duration for each instrument in the Reference Portfolio.
RiskCorrection	In the calculation of the fundamental spread on government bonds, this value represents the risk correction expressed as a proportion of the long-term average spread (LTAS).

Outputs

Name	Description
Spread	The spread of the reference portfolio, relative to the risk free rate. It is expressed as the internal effective rate, based on the specified composition of instruments.
RiskCorrection	The risk correction for the reference portfolio, based on the specified composition of instruments. For each of the instruments within the reference portfolio, the risk correction is defined as the fundamental spread.

CorpReferencePortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

The corporate reference portfolio.

Input variables

Name	Description
ReferencePortfolio	Specifies the instruments that make up the Corporate Reference Portfolio. Fill the following fields: • **RelativeMarketValue**—The relative market value for each instrument in the Reference Portfolio. • **Type**—The type of the instrument. Select **Financial** or **Non-Financial**. • **BasicRiskFreeModel**—The yield curve model that models EIOPA's risk free rate. • **AssetRiskFreeModel**—The relevant risk free yield curve model for each instrument in the Reference Portfolio. • **AssetCreditModel**—The relevant credit spread model for each instrument in the Reference Portfolio. • **CreditClass**—The credit class relevant to the credit model selected in AssetCreditModel. • **Duration**—The duration for each instrument in the Reference Portfolio.
RiskCorrection	In the calculation of the fundamental spread on corporate bonds, this value is the proportion of the long-term average spread (LTAS) applied in the risk correction.

Outputs

Name	Description
Spread	The spread of the reference portfolio, relative to the risk free rate. It is expressed as the internal effective rate, based on the specified composition of instruments.
RiskCorrection	The risk correction for the reference portfolio, based on the specified composition of instruments. For each of the instruments within the reference portfolio, the risk correction is defined as the fundamental spread.

RegulatoryCapital

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

You can add a RegulatoryCapital model to model relevant capital metrics for your managed portfolio group.

Addable submodels

Name	Description
SolvencyCapitalRequirement	Container for the Standard Formula Market SCR calculations

SolvencyCapitalRequirement

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

You can add a SolvencyCapitalRequirement model to model an approximate Standard Formula MarketSCR for your managed portfolio group. For more information on this calculation, see the *Scenario Generator Managed Portfolios Methodology Guide*.

Submodels

Name	Description
Interest	The InterestRate submodule
Equity	The Equity submodule
Property	The Property submodule
Spread	The Spread submodule
Currency	The Currency submodule
Concentration	The Concentration submodule

Input variables

Name	Description
Correlations	The correlations between submodules used in the calculation of MarketSCR.

Outputs

Name	Description
MarketSCR	The solvency capital requirement for the market risk module.
MarketSolvencyCapitalRatio [AssetValue]	The solvency capital ratio for the market risk module, calculated as follows: If TotalFairValue is selected: $\mathrm{MarketSolvencyCapitalRatio[FairValue]}(t) = \frac{\mathrm{TotalFairValue}_g(t) - \mathrm{TotalLiabilityValue}_g(t)}{\mathrm{MarketSCR}_g(t)}$ If TotalCarryingAmount is selected: $\mathrm{MarketSolvencyCapitalRatio[CarryingAmount]}(t) = \frac{\mathrm{TotalCarryingAmount}_g(t) - \mathrm{TotalLiabilityValue}_g(t)}{\mathrm{MarketSCR}_g(t)}$
Diversification	The difference between the sum of the components which make up the solvency capital requirement for the market risk module and the value of the MarketSCR. $\mathrm{Diversification}(t) = \mathrm{InterestRateSCR}(t) + \mathrm{EquitySCR}(t) + \mathrm{PropertySCR}(t) + \mathrm{SpreadSCR}(t) + \mathrm{CurrencySCR}(t) + \mathrm{ConcentrationSCR}(t) - \mathrm{MarketSCR}(t)$

Interest

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description
CorrelationOverride	The value that the pairs of correlations (Interest:Equity), (Interest:Property), and (Interest:Spread) should take if the interest SCR is determined by the down stress.
StressFactors	The stress factors to apply during the interest rate up and interest rate down stress.
MinimumUpStress	The minimum absolute value of the UpStress. This value is added to the spot rate term structure for relevant discount curves to create the minimum value that the spot rate will take in the interest up stress scenario.

Outputs

Name	Description
InterestRateSCR	The interest rate component of the solvency capital requirement for the market risk module.
UpStressSpotSpread [Economy, Maturity]	The spot spread for the interest rate up stress for the specified economy at the specified maturity. Calculated using the formula: $\mathrm{UpStressSpotSpread}(\mathrm{Economy}, \mathrm{Maturity}, t) = \mathrm{ZCBPStressUp}(\mathrm{Economy}, \mathrm{Maturity}, t)^{\frac{-1}{\mathrm{Maturity}}} - \mathrm{ZCBPBase}(\mathrm{Economy}, \mathrm{Maturity}, t)^{\frac{-1}{\mathrm{Maturity}}}$ where ZCBPStressUp is the zero-coupon bond price derived from the cubic spline of the respective stressed curve for the selected Economy and Maturity and ZCBPBase is the zero-coupon bond price of the NominalYieldCurve for the selected Economy and Maturity.
DownStressSpotSpread [Economy, Maturity]	The spot spread for the interest rate down stress for the specified economy at the specified maturity. Calculated using the formula: $\mathrm{DownStressSpotSpread}(\mathrm{Economy}, \mathrm{Maturity}, t) = \mathrm{ZCBPStressDown}(\mathrm{Economy}, \mathrm{Maturity}, t)^{\frac{-1}{\mathrm{Maturity}}} - \mathrm{ZCBPBase}(\mathrm{Economy}, \mathrm{Maturity}, t)^{\frac{-1}{\mathrm{Maturity}}}$ where ZCBPStressDown is the zero-coupon bond price derived from the cubic spline of the respective stressed curve for the selected Economy and Maturity and ZCBPBase is the zero-coupon bond price of the NominalYieldCurve for the selected Economy and Maturity.
BaseAssetValue	The aggregate fair value of the interest rate sensitive assets within the portfolio, reported in Group currency. This value is used in the calculation of BaseNAV for the InterestRateSCR calculation.
UpStressAssetValue	The aggregate fair value of the interest rate sensitive assets within the portfolio when the UpStress has been applied, reported in Group currency. This value is used in the calculation of StressUpNAV for the InterestRateSCR calculation.

Name	Description
DownStressAssetValue	The aggregate fair value of the interest rate sensitive assets within the portfolio when the UpStress has been applied, reported in Group currency. This value is used in the calculation of StressUpNAV for the InterestRateSCR calculation.

Equity

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description	Condition
StressFactor	The stress factor to apply to the value of equity assets.	
SymmetricAdjustmentType	The type of symmetric adjustment to apply. Select **Constant** or **Dynamic**.	
Constant	The constant value for the symmetric adjustment.	Enabled only if **SymmetricAdjustmentType** is **Constant**.
IndexHistory	The last 36 months index history for the equity asset used in the dynamic symmetric adjustment. The value entered in row 1 should represent the most recent value of this index.	Enabled only if **SymmetricAdjustmentType** is **Dynamic**.
ReferenceEquityIndex	The reference equity index to use when projecting the dynamic symmetric adjustment.	Enabled only if **SymmetricAdjustmentType** is **Dynamic**.
SAConstant	The constant applied to adjust the equity indices in the calculation of the dynamic symmetric adjustment.	Enabled only if **SymmetricAdjustmentType** is **Dynamic**.

Outputs

Name	Description
EquitySCR	The equity component of the solvency capital requirement for the market risk module.
SymmetricAdjustment	The symmetric adjustment used in the calculation of the EquitySCR.

Property

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description
StressFactor	The stress factor to apply to the value of property assets.

Outputs

Name	Description
PropertySCR	The property component of the solvency capital requirement for the market risk module.

Spread

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description
MultiplicativeStress	The multiplicative stress factor to apply to bonds specified by duration and credit class.
AdditiveStress	The additive stress factor to apply to bonds specified by duration and credit class.

Outputs

Name	Description
SpreadSCR	The spread component of the solvency capital requirement for the market risk module.

Currency

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description
EconomyStressFactor	The stress factors to apply during the currency up and currency down stress.

Outputs

Name	Description
CurrencySCR	The currency component of the solvency capital requirement for the market risk module.

Concentration

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description
Scalar	The value of the concentration risk as a proportion of the sum of the other sub-modules.

Outputs

Name	Description
ConcentrationSCR	The concentration component of the solvency capital requirement for the market risk module.

Overlay

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Submodels

Name	Description
InitialHoldings	Defines the time zero asset holdings of the Overlay portfolio.
OverlayStrategy	Defines the investment strategy for assets within the Overlay portfolio.

Input variables

Name	Description
Economy	The economy of the overlay.

Outputs

Name	Description
TotalFairValue	The market value of the overlay. This value reflects the entire overlay including all assets currently held. $$\mathrm{FairValue}_p(t) = \sum_{a \in P_p} \mathrm{FairValue}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the overlay, respectively.
TotalFairValueReturn	The total of the fair value return across all assets held by the overlay, *p*, regardless of accounting convention. $$\mathrm{TotalFairValueReturn}_p(t) = \frac{\mathrm{TotalFairValue}_p(t) + \mathrm{AssetCashOut}(t)}{\mathrm{TotalFairValue}(t - \Delta t)} - 1$$ To fairly reflect the performance of the overlay, the fair value return is adjusted as described below. • Any cash flows generated by the assets in the portfolio that have been directed to the group cash account are added on. The initial fair value return is zero: $\mathrm{TotalFairValueReturn}_p(0) = 0$.
TotalPayerNotional	The aggregate notional value of the payer swaps being held in the overlay: $$\mathrm{TotalPayerNotional}_p(t) = \sum_{a_{Payer} \in P_p} \mathrm{Notional}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the overlay, respectively.
TotalReceiverNotional	The aggregate notional value of the receiver swaps being held in the overlay: $$\mathrm{TotalReceiverNotional}_p(t) = \sum_{a_{Receiver} \in P_p} \mathrm{Notional}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the overlay, respectively.
TotalCarryingAmount	The carrying amount of the assets in the overlay. This value reflects the entire portfolio including all assets currently held. $$\mathrm{CarryingAmount}_p(t) = \sum_{a \in P_p} \mathrm{CarryingAmount}_a(t) \times \frac{X_p(t)}{X_a(t)}$$ where: • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the overlay, respectively.
TotalOrdinaryIncome	Investment income received in the form of the aggregate net payments from the swap contracts. For swaps classified as FairValuePNL, $$\mathrm{OrdinaryIncome}_a(t) = \mathrm{NetPayment}_a(t)$$ where: • X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the portfolio, respectively.

Name	Description
TotalEarnings	The earnings value at each time step, reported in the currency of the overlay. $$\begin{aligned}\mathrm{TotalEarnings}(t) = {} & \mathrm{TotalOrdinaryIncome}(t) - \mathrm{TotalDefaultLoss}(t) - \mathrm{TotalImpairmentLoss}(t) \\ & + \mathrm{TotalRealisedGain}(t) + \mathrm{CurrencyHedgeIncome}(t) \\ & + \sum_{FairValuePNL\, a \in P_p} \left(\mathrm{CarryingAmount}_a(t) - \mathrm{CarryingAmount}_a(t-dt)\right) \times \frac{X_p(t)}{X_a(t)}\end{aligned}$$ When using asymmetric output settings, this output will equal the sum of the TotalEarnings (calculated using the equation above) at each of the intermediate time steps. **Note** Swaps cannot default or be currency hedged, and as swaps are classified as FairValuePNL assets, they also cannot impair and will not create realized gain.
TotalBookReturn	The total of the book return across all assets held by the overlay, *p*. $$\mathrm{TotalBookReturn}_p(t) = \frac{\mathrm{TotalCarryingAmount}_p(t) + \mathrm{AssetCashOut}(t)}{\mathrm{TotalCarryingAmount}_p(t - \Delta t)} - 1$$ To fairly reflect the performance of the overlay, the book return is adjusted as described below. • Any cash flows generated by the assets in the overlay that have been directed to the group cash account are added on. The initial book return is zero: $\mathrm{TotalBookReturn}_p(0) = 0$
TotalCurrencyTranslationGain	Absolute measure of gains or losses (if negative) that have occurred due to exchange rate movements at each time step, for all assets within the overlay. This output is reported in the currency of the overlay.
DurationValue	The product of duration and fair value of the overlay. It is calculated as the sum of the product of duration and fair value (denoted DurationValue) of all individual swaps in the overlay when converted to the currency of the overlay. The DurationValue of overlay *p* is: $$\mathrm{DurationValue}_p(t) = X_p(t) \times \sum_{a \in P_p} \frac{\mathrm{DurationValue}_a(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the overlay, respectively. For the calculation of DurationValue for an individual swap, see the *Scenario Generator Managed Portfolios Methodology Guide*. Note that these quantities are dependent on the fair values of the individual swap holdings which is implicitly dependent on their notional principal. The duration will be undefined when the fair value is zero. Where it is defined, the duration can be determined by dividing DurationValue by the TotalFairValue of the overlay.
ConvexityValue	The product of convexity and fair value of the overlay. It is calculated as the sum of the product of convexity and fair value (denoted ConvexityValue) of all individual swaps in the overlay when converted to the currency of the overlay. The ConvexityValue of overlay, *p*, is: $$\mathrm{ConvexityValue}_p(t) = X_p(t) \times \sum_{a \in P_p} \frac{\mathrm{ConvexityValue}_a(t)}{X_a(t)}$$ where X_a and X_p are the nominal exchange rates, with respect to the base economy, of the economy of the asset and the economy of the overlay, respectively. For the calculation of ConvexityValue for an individual swap, see the *Scenario Generator Managed Portfolios Methodology Guide*. Note that these quantities are dependent on the fair values of the individual swap holdings which is implicitly dependent on their notional principal. The convexity will be undefined when the fair value is zero. Where it is defined, the convexity can be determined by dividing ConvexityValue by the TotalFairValue of the overlay.

InitialHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Addable submodels

Name	Description
SwapHoldings	Define the swap holdings at time zero.

SwapHoldings

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description
SwapHoldings	Define the swap holdings at time zero. For each holding, fill the following fields: • **Economy**—The economy in which the swap is denominated. • **PricingCurve**—The yield curve that is used for discounting cash flows as part of the price calculation. • **CouponCurve**—The yield curve from which the rates for coupons are obtained at each reset date. • **NotionalPrincipal**—The notional principal of the swap contract. • **Type**—The type of the swap. Either **Receiver** (receiving fixed) or **Payer** (paying fixed). • **Term**—The term to maturity of the swap in years from the beginning of the simulation, that is, the amount of time remaining on the swap. • **SwapRate**—The annualized fixed rate payable by the fixed side of the swap. • **Frequency**—The number of payment dates per year. Each payment date is also assumed to be a reset date. • **LastResetRate**—The annualized reset rate, set at some point in the past, that the next payment on the floating side of the swap is based on. This is only used if t=0 is not a reset date.

OverlayStrategy

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Addable submodels

Name	Description
SwapHedge	Defines the swap hedging strategy for the overlay. There can only be one SwapHedge in the overlay, but to define multiple hedges dealing with different liabilities and managed portfolios, you can define additional Overlays.

SwapHedge

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Input variables

Name	Description
Type	Select the type of the hedge: • Duration • Duration and Convexity
Time0Calculation	Select whether the hedge should be calculated at time zero.
HedgeAllLiabilities	Select whether all liability cash flows should be hedged.
Liabilities	Select the subsets of liabilities whose duration and/or convexity should be hedged.
Assets	Select the subsets of managed portfolios that contain assets whose duration, and convexity if applicable, should contribute to the hedge.
Economy	The economy of the hedging swaps.
PricingCurve	The yield curve that will be used for discounting cash flows as part of the price calculation.
CouponCurve	The yield curve from which the rates for coupons will be obtained at each reset date.
Frequency	The number of payments per year for the hedging swaps, which is also the number of resets per year.
SwapTerm1	The term to maturity (in years) of a hedging swap at origination.
SwapTerm2	The term to maturity (in years) of the other hedging swap at origination. This must be different to the term entered under the SwapTerm1 parameter. Disabled if **Type** is set to **Duration**.

Outputs

Name	Description
NewPayerNotional	The aggregate notional value of payer swaps entered into over the time step, reported in the currency of the overlay.
NewReceiverNotional	The aggregate notional value of receiver swaps entered into over the time step, reported in the currency of the overlay.
TotalAssetDV	The aggregate of the product of duration and fair value for the specified hedging assets, reported in the currency of the overlay.

Name	Description
TotalLiabilityDV	The aggregate of the product of duration and fair value for the liabilities specified to hedge, reported in the currency of the overlay.
TotalSwapDV	The aggregate of the product of duration and fair value for the swaps held in the overlay up to the hedging time step, reported in the currency of the overlay.
TotalAssetCV	The aggregate of the product of convexity and fair value for the specified hedging assets, reported in the currency of the overlay.
TotalLiabilityCV	The aggregate of the product of convexity and fair value for the liabilities specified to hedge, reported in the currency of the overlay.
TotalSwapCV	The aggregate of the product of convexity and fair value for the swaps held in the overlay up to the hedging time step, reported in the currency of the overlay.

For information on the calculation of the preceding outputs, see the *Scenario Generator Managed Portfolios Methodology Guide*.

5.3 AdvancedAssetPortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Contains advanced asset portfolios.

Addable submodels

Name	Description
AdvancedPortfolio	Asset portfolios including cash, generic assets, and derivatives portfolios.

5.3.1 AdvancedPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Advanced portfolio is a container for Asset portfolios including cash, generic assets, and derivatives portfolios.

Containers

Name	Description
AssetPortfolios	Container which holds the various asset portfolios.

Input variables

Name	Description
Economy	The base economy for this AdvancedPortfolio

AssetPortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This container holds all the various portfolios of assets that the Fund holds. The model aggregates the value and cash flows of all the asset portfolios it contains.

The advanced asset portfolios use a *netcashflow* manager to reinvest asset cash flows which are generated that are not automatically reinvested, *for example*, when a bond matures or when it pays coupons where you have set **ReinvestCashflows** to **No**. The netcashflow manager uses a priority-based system, determined by the **InvestNetCashflowIn** and **WithdrawFrom** values that you specify. The netcashflow manager considers only portfolios with a non-zero value when determining where to invest the cash flow. If the portfolio with the highest priority has a zero value, then the netcashflow manager checks the next on the list until it finds a portfolio with a non-zero value.

After the netcashflow manager has exhausted the priorities that you specify, it considers all remaining portfolios. If there are no eligible portfolios, then the cash flow is invested in CashPortfolios.CashPortfolio.

Submodels

Name	Description
Rebalancing	Model that defines how rebalancing is conducted at the high level. That is, between asset portfolios.

Containers

Name	Description
CashPortfolios	Container which holds the cash only asset portfolios.

Addable containers

Name	Description
GenericAssetPortfolios	Container which holds various non-derivative asset portfolios.

Name	Description
DerivativePortfolios	Container which holds derivative portfolios.

Input variables

Name	Description
WithdrawFrom	Priorities of asset portfolios from which negative cash flows in the fund can be withdrawn. You can select priorities of 1–9, where 1 is the highest priority. You can assign the same priority to multiple portfolios. **Note** You cannot assign cash flows to derivative portfolios or generic shorting portfolios.
InvestNetCashflowsIn	Priorities of asset portfolios into which cash flows in the fund can be invested. You can select priorities of 1–9, where 1 is the highest priority. You can assign the same priority to multiple portfolios. **Note** You cannot assign cash flows to derivative portfolios or generic shorting portfolios.

Outputs

Name	Description
Value	The total value of the portfolio.
Cashflow	The total cash flows of the portfolio.
IncomeReturn	The income return of the portfolio.
CapitalChange	The capital change of the portfolio.
TotalReturn	The total return of the portfolio.
TotalReturnIndex	The total return index of the portfolio.

Rebalancing

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Rebalancing of the portfolios can take several strategies dependent on the type of the Rebalancing model. To change the type, and therefore the rebalancing strategy, right-click the rebalancing model, and select Change Model Type.

Rebalancing at this level does not affect the asset allocation of the with in portfolio collections.

Note If all portfolios are depleted except for cash, then rebalancing is terminated (no rebalancing is conducted) for the remainder of the time steps.

The following table lists the available types. In each case, a Comments parameter is available for notes, but this parameter plays no part in any calculations.

Available types

Name	Description
NoRebalancing	No rebalancing is conducted.
InitialProportionRebalancing	Rebalancing is conducted to maintain the same asset allocation as at the beginning of the simulation. The initial asset proportions (excluding derivatives and shorting portfolios) are assessed at the beginning of the simulation and the rebalancing seeks to maintain these proportions at the end of each time step. On maturity of an entire portfolio collection (Maturity is determined when the portfolio value equates to 0), the maturing portfolio collection's allocation is reassigned on a proportional basis to the remaining (non-derivative, non-shorting) portfolios. No adjustment is made on partial maturity of a portfolio collection. When using initial proportion rebalancing, InvestNetCashflowsIn and WithdrawFrom should be empty.
BoundaryRebalancing	Rebalancing is conducted according to a set of rules. The available inputs to this type of model are: • **Comments**—Use this parameter to make notes about the rebalancing. The software ignores the comments when running the simulation. • **Rules**—Specify the rules that define whether rebalancing is to be conducted. These rules are shown in the following table. • **RebalanceTo**—When triggered, rebalancing is conducted back to the central benchmark. Rebalancing is triggered by any breach of the Rules specified in the following table. When rebalancing is conducted, the breached portfolios are rebalanced back to their central benchmarks. The remaining portfolios are allocated any excess/deficit on a basis relative to how over/under weight bringing the remaining portfolios closer inline with their central benchmark. Maturing portfolio collections are reallocated on a proportional basis. Maturity is determined when the portfolio value equates to 0.

Boundary rebalancing rules

Rule	Description
PortfolioName	Portfolio to which the rule applies.
Central	Specifies the central benchmark that the portfolio is rebalanced to if the upper or lower limit is breached.
Upperlimit	Specifies the upper limit that triggers rebalancing.
Lowerlimit	Specifies the lower limit that triggers rebalancing.

The rules must comply to the following:

- Central must sum to 1
- Upperlimit must be greater than Central.
- Lowerlimit must be less than Central.

CashPortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Cash portfolios.

Submodels

Name	Description
Rebalancing	Model that defines how rebalancing is conducted at the low level, that is, within cash portfolios.
CashPortfolio	Portfolio containing only cash assets.

Addable submodels

Name	Description
CashPortfolio	Portfolio containing only cash assets. Any number of extra cash portfolios can be added.

Outputs

Name	Description
Value	Total aggregated value of portfolios at time step t after rebalancing.
PreRebalancingValue	Total aggregated value of portfolios at time step t before rebalancing.
Cashflows	Total aggregated cash flow from the portfolios over time step t-dt to t.
TotalReturn	The total return generated by the portfolio.
TotalReturnIndex	The total return index generated by the fund.
CapitalChange	The capital change generated by the portfolio.
IncomeReturn	The income return generated by the portfolio.

Rebalancing

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Rebalancing of the portfolios can take several strategies dependent on the type of the Rebalancing model. To change the type, and therefore the rebalancing strategy, right-click the rebalancing model, and select Change Model Type. Rebalancing at this level is conducted after the rebalancing at the asset portfolios level is done.

The following table lists the available types. In each case, a Comments parameter is available for notes, but this parameter plays no part in any calculations.

Available types

Name	Description
NoRebalancing	No rebalancing is conducted.
InitialProportionRebalancing	Rebalancing is conducted to maintain the same asset allocation as at the beginning of the simulation. The initial asset proportions (excluding derivatives and shorting portfolios) are assessed

Name	Description
	at the beginning of the simulation and the rebalancing seeks to maintain these proportions at the end of each time step. On maturity of an asset the allocation to that asset is redistributed to the remaining assets in the portfolio on a proportional basis. If no assets remain in the portfolio, then the allocation is redistributed to the remaining portfolios on a proportional basis.
BoundaryRebalancing	Rebalancing is conducted according to a set of rules. The available inputs to this type of model are: • **Comments**—Use the comments parameter to make notes about the rebalancing. The software ignores comments when running the simulation. • **Rules**—Specify the rules that define whether rebalancing is to be conducted. These rules are shown in the following table. • **RebalanceTo**—When triggered, rebalancing is conducted back to the central benchmark. Rebalancing is triggered by any breach of the Rules specified in the following table. When rebalancing is conducted, the breached portfolios is rebalanced back to their central benchmarks. The remaining portfolios are allocated any excess/deficit on a basis relative to how over/under weight bringing the remaining portfolios closer inline with their central benchmark. Maturing portfolios are reallocated on a proportional basis. If a portfolio only partially matures, no adjustment is made.

Boundary rebalancing rules

Name	Description
PortfolioName	Portfolio to which the rule applies.
Central	Specifies the central benchmark that the portfolio is rebalanced to if the upper or lower limit is breached.
Upperlimit	Specifies the upper limit that triggers rebalancing.
Lowerlimit	Specifies the lower limit that triggers rebalancing.

The rules must comply to the following:

- Central must sum to 1.
- Upperlimit must be greater than Central.
- Lowerlimit must be less than Central.

CashPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Cash portfolio.

Input variables

Name	Description
Holdings	The holdings of the portfolio. The holdings specify the amount of each asset, the management charge and if currency risk is hedged or not. For each holding, fill the following values: • **AssetName**—The asset.

Name	Description
	• **Value**—The value of the asset, in the currency of the portfolio. • **ManagementCharge**—The management charge for the asset. *For example*, for a 1% charge, enter 0.01. • **CurrencyHedge**—Select whether there is currency hedging. The currency hedging calculations use the nominal yield curve that you define in Economies.Economy.NominalYieldCurves.CurrencyHedgeCurve, for the economy of the asset and the economy of the portfolio.
ActiveManagement	The active management used in the portfolio. The models are specified in the ActiveManagementModels node.

Outputs

Name	Description
Value	The total value of all the portfolio's holdings at time step t after rebalancing.
PreRebalancingValue	The total value of portfolios at time step t before rebalancing.
Cashflow	The total cash flow from all the portfolio's holdings during time step t-dt to t.
TotalReturn	The total return on cash over the previous time step.
TotalReturnIndex	The total return index of the portfolio. $\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t - \Delta t) \times (1 + \mathrm{TotalReturn}(t))$ where TotalReturnIndex(0) = 1.
CapitalChange	The TotalReturn minus the IncomeReturn.
CapitalIndex	The capital index of an asset. $\mathrm{CapitalIndex}(t) = \mathrm{CapitalIndex}(1 - \Delta t) \times (1 + \mathrm{CapitalChange}(t))$ where CapitalIndex(0) = 1.0.
IncomeReturn	The cash flow expressed as a proportion of the value of the portfolio at the start of the time step.

GenericAssetPortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Generic asset portfolios.

Submodels

Name	Description
Rebalancing	Model that defines how rebalancing is conducted at the low level. That is, within generic asset portfolios. Generic asset shorting portfolios are excluded from rebalancing.

Addable submodels

Name	Description
GenericAssetPortfolio	Portfolio containing "long"-only non-derivative assets, that is, the holdings must be positive.
GenericAssetShortingPortfolio	Portfolio containing "long" and "short" non-derivative assets, that is, the holdings can be positive or negative. (Excluded from rebalancing)

Outputs

Name	Description
Value	Total aggregated value of portfolios at time step t after rebalancing.
PreRebalancingValue	Total aggregated value of portfolios at time step t before rebalancing.
Cashflow	Total aggregated cash flow from the portfolios over time step t-dt to t.
IncomeReturn	The income return generated by the portfolio.
CapitalChange	The capital change generated by the portfolio.
TotalReturn	The total return generated by the portfolio.
TotalReturnIndex	The total return index generated by the fund.

Rebalancing

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Rebalancing of the portfolios can take several strategies dependent on the type of the Rebalancing model. To change the type, and therefore the rebalancing strategy, right-click on the rebalancing model, and select Change Model Type. Rebalancing at this level is conducted after the rebalancing at the asset portfolios level is done.

The following table lists the available types. In each case, a Comments parameter is available for notes, but this parameter plays no part in any calculations.

Rebalancing types

Name	Description
NoRebalancing	No rebalancing is conducted.
InitialProportionRebalancing	Rebalancing is conducted to maintain the same asset allocation as at the beginning of the simulation. The initial asset proportions (excluding derivatives and shorting portfolios) are assessed at the beginning of the simulation and the rebalancing seeks to maintain these proportions at the end of each time step. On maturity of an asset the allocation to that asset is redistributed to the remaining assets in the portfolio on a proportional basis. If no assets remain in the portfolio, then the allocation is redistributed to the remaining portfolios on a proportional basis.

Name	Description
BoundaryRebalancing	Rebalancing is conducted according to a set of rules. The available inputs to this type of model are: • **Comments**—Use the comments parameter to make notes about the rebalancing. The software ignores comments when running the simulation. • **Rules**—Specify the rules that define whether rebalancing is to be conducted. These rules are shown in the following table. • **RebalanceTo**—When triggered rebalancing is conducted back to the central benchmark.

Boundary rebalancing rules

Name	Description
PortfolioName	Portfolio to which the rule applies.
Central	Specifies the central benchmark that the portfolio is rebalanced to if the upper or lower limit is breached.
Upperlimit	Specifies the upper limit that triggers rebalancing.
Lowerlimit	Specifies the lower limit that triggers rebalancing.
The rules must comply to the following: • Central must sum to 1 • Upperlimit must be greater than Central. • Lowerlimit must be less than Central.	

GenericAssetPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Generic asset portfolio.

Input variables

Name	Description
Holdings	The holdings of the portfolio. The holdings specify the amount of each asset, the management charge and if currency risk is hedged or not. Holdings must be positive. For each holding, fill the following values: • **AssetName**—The asset. • **Value**—The value of the asset, in the currency of the portfolio. • **ManagementCharge**—The management charge for the asset. *For example*, for a 1% charge, enter 0.01. • **ReinvestCashflows**—Select whether you want to automatically reinvest cash flows of the asset holding in the portfolio. • **CurrencyHedge**—Select whether there is currency hedging. The currency hedging calculations use the nominal yield curve that you define in Economies.Economy.NominalYieldCurves.CurrencyHedgeCurve, for the economy of the asset and the economy of the portfolio.

Name	Description
ActiveManagement	The active management used in the portfolio. The models are specified in the ActiveManagementModels node.

Outputs

Name	Description
Value	The total value of all the holdings in the portfolio at time step t.
PreRebalancingValue	The total value of portfolios at time step t before rebalancing.
Cashflow	The total cash flow from all the portfolio's holdings during time step t-dt to t.
TotalReturn	The total return of the portfolio over the previous time step.
TotalReturnIndex	The total return index of the portfolio. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = 1.
CapitalChange	The TotalReturn minus the IncomeReturn.
CapitalIndex	The capital index of an asset. $\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$ where CapitalIndex(0) = 1.0.
IncomeReturn	The cash flow expressed as a proportion of the value of the portfolio at the start of the time step.

GenericAssetShortingPortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Generic asset shorting portfolio.

Input variables

Name	Description
Holdings	The holdings of the portfolio. The holdings specify the amount of each asset, the management charge and if currency risk is hedged or not. Holdings can be positive or negative. For each holding, fill the following values: • **AssetName**—The asset. • **Value**—The value of the asset, in the currency of the portfolio. • **ManagementCharge**—The management charge for the asset. *For example*, for a 1% charge, enter 0.01. • **ReinvestCashflows**—Select whether you want to automatically reinvest cash flows of the asset holding in the portfolio. • **CurrencyHedge**—Select whether there is currency hedging. The currency hedging calculations use the nominal yield curve that you define in

Name	Description
	Economies.Economy.NominalYieldCurves.CurrencyHedgeCurve, for the economy of the asset and the economy of the portfolio.
ActiveManagement	The active management used in the portfolio. The models are specified in the ActiveManagementModels node.

Outputs

Name	Description
Value	The total value of all the holdings in the portfolio at time step t.
PreRebalancingValue	The total value of portfolios at time step t before rebalancing.
Cashflow	The total cash flow from all the portfolio's holdings during time step t-dt to t.
TotalReturn	The total return of the portfolio over the previous time step.
TotalReturnIndex	The total return index of the portfolio. $\mathrm{TotalReturnIndex}(t) = \mathrm{TotalReturnIndex}(t - \Delta t) \times (1 + \mathrm{TotalReturn}(t))$ where TotalReturnIndex(0) = 1.
CapitalChange	The TotalReturn minus the IncomeReturn.
CapitalIndex	The capital index of an asset. $\mathrm{CapitalIndex}(t) = \mathrm{CapitalIndex}(t - \Delta t) \times (1 + \mathrm{CapitalChange}(t))$ where CapitalIndex(0) = 1.0.
IncomeReturn	The cash flow expressed as a proportion of the value of the portfolio at the start of the time step.

DerivativePortfolios

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Derivative portfolios.

Submodels

Name	Description
Rebalancing	Derivative portfolios cannot be rebalanced. NoRebalancing is set as default and cannot be changed.

Addable submodels

Name	Description
DerivativePortfolio	Portfolio containing only derivative assets.

Outputs

Name	Description
Value	Total aggregated value of portfolios at time step t after rebalancing.
Cashflows	Total aggregated cashflow from the portfolios over time step t-dt to t.
IncomeReturn	The income return generated by the portfolio.
CapitalChange	The capital change generated by the portfolio.
TotalReturn	The total return generate by the portfolio.

Rebalancing

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Derivative portfolios cannot be rebalanced. NoRebalancing is set and cannot be changed.

DerivativePortfolio

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Derivative portfolio.

Input variables

Name	Description
Holdings	The holdings of the portfolio. For each holding, fill the following values: • **AssetName**—The asset. • **Value**—The value of the asset, in the currency of the portfolio. • **CurrencyHedge**—Select whether there is currency hedging. The currency hedging calculations use the nominal yield curve that you define in Economies.Economy.NominalYieldCurves.CurrencyHedgeCurve, for the economy of the asset and the economy of the portfolio.

Outputs

Name	Description
Value	The total value of all the holdings in the portfolio at time step t.
Cashflow	The total cash flow from all the holdings in the portfolio during time step t-dt to t.
TotalReturn	The total return of the portfolio over the previous time step.

Name	Description
TotalReturnIndex	The total return index of the portfolio. $\text{TotalReturnIndex}(t) = \text{TotalReturnIndex}(t - \Delta t) \times (1 + \text{TotalReturn}(t))$ where TotalReturnIndex(0) = 1.
CapitalChange	The TotalReturn minus the IncomeReturn.
CapitalIndex	The capital index of an asset. $\text{CapitalIndex}(t) = \text{CapitalIndex}(t - \Delta t) \times (1 + \text{CapitalChange}(t))$ where CapitalIndex(0) = 1.0.
IncomeReturn	The cash flow expressed as a proportion of the value of the portfolio at the start of the time step.
Duration	Duration of the portfolio.

6 ActiveManagementModels

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

You can add some active management risk to advanced asset portfolios and unit funds. Active management models enable you to introduce risk due to investment manager overperformance or underperformance.

Submodels

Name	Description
NoActiveManagement	Model for no active management.

Addable submodels

Name	Description
ActiveManagement	White noise model to model overperformance or underperformance relative to the modeled index.

6.1 NoActiveManagement

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

If you use this model, the index is assumed to be tracked perfectly. Assign this model to assets where there is a passive investment strategy.

6.2 ActiveManagement

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This model is a white noise model. It uses a tracking error and an alpha assumption to add volatility to investment returns.

The model makes the following assumptions:

- Active management is uncorrelated to other asset returns and market performance.
- The return from each period is independent of the previous time step.
- The period shock is normally distributed.

Input variables

Name	Description	Conditions
Alpha	The expected excess return (gross of fees) in respect of the active management.	Enabled only if the simulation-level **UseRiskNeutralValuation** parameter is **False**.
TrackingError	The expected volatility of the excess return.	

Outputs

Name	Description
ActiveReturn	The excess return generated by active management over the previous time step, defined as $(1+\mathrm{Alpha})^{\Delta t_n} \exp\left(-\frac{1}{2}\sigma^2 \Delta t_n + \sigma\sqrt{\Delta t_n}\Delta Z_n\right) - 1$ where Δt_n is the time step length, σ is the TrackingError, and $\Delta Z_n \sim N(0,1)$.
NetInformationRatio	This is equal to Alpha/TrackingError.

7 Processors

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The processors node enables you to create custom calculations for software outputs. For more information about how to use processors, see the Processors user guide section.

Addable submodels

Name	Description
Processor	An individual processor, which can perform one calculation. You can also add other processors as addable submodels to processors.

Input variables

Name	Description
Global Variables	Global variables are software outputs that you can use in all processors under this node.
Global Constants	Global constants are constant values that you can use in all processors under this node.
PreT0LagBehaviour	Defines how the software handles output lags that result in a pre-time zero output. Select one of the following options: • **0**—Output a zero for all pre-time step zero outputs. • **NaN**—Output a NaN for all pre-time step zero outputs. • **UseT0Value**—For pre-time step zero outputs, use the time zero value. You cannot use this option if you use self-referencing in any processors. *For example*, if you have a variable with a lag of 4, and you select **0** for the **PreT0LagBehaviour**, the value for that variable that the software uses in the calculation at time 0, 1, 2, and 3 is 0.

7.1 Processor

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

Set up a processor for each output calculation that you want to perform. For more information about the operators and functions available to processors, see the Processors user guide section.

Addable submodels

Name	Description
ConstantCollection	A collection of constants.
VariableCollection	A collection of variables.
Processor	A nested processor. The input variables, outputs, and addable submodels are the same for a processor at any level in the tree.

Input variables

Name	Description
LinkedProcessors	Select the processors that you want to use as variables in this processor. For each processor, fill the following values: • **Name**—A name for the variable. For naming constraints, see the Processors user guide section. • **Output**—The processor to use for this variable.
Variables	Local variables for this calculation. For each variable, fill the following values: • **Name**—A name for the variable. For variable naming constraints, see the Processors user guide section. • **Output**—The output to use for this variable. • **Lag**—To use the output value from a previous time step, enter the number of time steps to go back. *For example*, if you enter 2, the software uses the time step three value for the output at time step five.
Constants	Local constants for this calculation. For each constant, fill the following values: • **Name**—A name for the constant. For constant naming constraints, see the Processors user guide section. • **Constant**—The constant value. This value must be a number.
Calculation	The calculation that you want to perform. For more information about the calculation format, see the Processors user guide section.

Outputs

Name	Description
Value [Row]	The value of the processor, based on the calculation that you define, at the specified row.
Mean	The mean of the calculated values.

Name	Description
Sum	The sum of the calculated values.
Product	The product of the calculated values.
NumberOfRows	The number of rows in the Value array.

7.1.1 ConstantCollection

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A collection of constants to use in a processor calculation. You can perform calculations between constant and variable collections with the same number of rows, and standard variables and constants.

Input variables

Name	Description
Constants	The constants that you want to include in the constant collection.

Outputs

Name	Description
Value [Row]	The value of the collection, that you have defined, at the specified row.
Mean	The mean of the constants.
Sum	The sum of the constants.
Product	The product of the constants.
NumberOfRows	The number of rows in the Value array.

7.1.2 VariableCollection

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

A collection of variables which can be used in a processor calculation. You can perform calculations between constant and variable collections with the same number of rows, and standard variables and constants.

Note You can add a set of variables that are based on the same software output, with different parameter values. To add multiple variables, click **Add Multiple Outputs**, select the model and output, and click **Next.** Then, use **CTRL+CLICK** to select the parameter values that you want to include in the variable collection, and click **OK**.

Input variables

Name	Description
Outputs	The output values that you want to include in the variable collection. Fill the following values for each output. • **Output**—The software output. • **Lag**—The number of time steps for which the output is lagged.

Outputs

Name	Description
Value [Row]	The value of the collection, based on the output and the lag that you selected, at the specified row.
Mean	The mean of the variables.
Sum	The sum of the variables.
Product	The product of the variables.
NumberOfRows	The number of rows in the Value array.

8 RiskDrivers

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	Yes

The RiskDrivers node is a container that can hold several peripheral risk drivers. There is a variety to choose from, and any number and combination of risk drivers can be added to this container. Some of the risk drivers are structural, meaning that they are defined by stochastic differential equations which govern their evolution over time. Others are purely statistical meaning that they have the same distribution for all time steps.

This feature is useful if you want to do external stochastic calculations of aspects not supported in the core models in parallel with a simulation. Except for the GaussianRiskDriverIndependent version, you can correlate all of these risk drivers with existing models or other risk drivers via the correlation matrix.

Addable submodels

Name	Description	Availability
GaussianRiskDriverIndependent	A risk driver with a Gaussian distribution that cannot be correlated with other risk drivers/shocks as it does not appear in the correlation matrix.	ESG
GaussianRiskDriver	A risk driver with a Gaussian distribution.	ESG
NormalMeanRevertingRiskDriver	A mean-reverting normally distributed risk driver.	ESG
LogNormalMeanRevertingRiskDriver	A mean-reverting risk driver with lognormal distribution.	ESG
SquareRootMeanRevertingRiskDriver	A mean-reverting normally distributed risk driver.	ESG
UniformRiskDriver	A uniformly distributed risk driver.	ESG
LogNormalRiskDriver	A risk driver with a lognormal distribution.	ESG
StudentTRiskDriver	A risk driver with a student t distribution.	ESG
GeneralisedParetoRiskDriver	A risk driver with a generalized Pareto distribution.	ESG
GeneralisedLambdaRiskDriver	A risk driver with a generalized lambda distribution.	ESG
EGB2RiskDriver	A risk driver with an exponential generalized beta distribution of the second kind (EGB2) distribution.	ESG
PoissonRiskDriver	A risk driver with a Poisson distribution.	ESG

Name	Description	Availability
EmpiricalRiskDriver	A flexible risk driver with distribution defined empirically via raw data samples or defined via percentiles.	ESG
GaussianRiskDriverIndependentAutoCorrelated	A risk driver with a Gaussian distribution that cannot be correlated with other risk drivers/shocks as it does not appear in the correlation matrix.	RSG
GaussianRiskDriverAutoCorrelated	A risk driver with a Gaussian distribution.	RSG
UniformRiskDriverAutoCorrelated	A uniformly distributed risk driver.	RSG
LogNormalRiskDriverAutoCorrelated	A risk driver with a lognormal distribution.	RSG
StudentTRiskDriverAutoCorrelated	A risk driver with a student t distribution.	RSG
GammaRiskDriverAutoCorrelated	A risk driver with a gamma distribution.	RSG
NonCentralChiSquaredRiskDriver	A risk driver with a non-central chi squared distribution.	RSG
GeneralisedParetoRiskDriverAutoCorrelated	A risk driver with a generalized Pareto distribution.	RSG
GeneralisedLambdaRiskDriverAutoCorrelated	A risk driver with a generalized lambda distribution.	RSG
EGB2RiskDriverAutoCorrelated	A risk driver with an exponential generalized beta distribution of the second kind (EGB2) distribution.	RSG
PoissonRiskDriverAutoCorrelated	A risk driver with a Poisson distribution.	RSG
ParetoCompoundPoissonRiskDriverAutoCorrelated	A risk driver with a Pareto compound Poisson distribution.	RSG
EmpiricalRiskDriverAutoCorrelated	A flexible risk driver with distribution defined empirically via raw data samples or defined via percentiles.	RSG

8.1 GaussianRiskDriverIndependent

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This model can be used to represent a risk factor that has a Gaussian distribution with a specified mean and standard deviation.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

This model is independent of all other models in that it does not appear in the correlation matrix. Use the GaussianRiskDriver for a correlated version.

Input variables

Name	Description
Mean	The mean of the Gaussian distribution of this risk driver, which corresponds to the mean, median and mode if the risk driver is unbounded.
StandardDeviation	The standard deviation of the Gaussian distribution of this risk driver, which corresponds to the standard deviation when the risk driver is unbounded.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the Gaussian distribution with the given mean and standard deviation.

8.2 GaussianRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This model can be used to represent a risk factor that has a Gaussian distribution with a specified mean and standard deviation. This risk driver has no notion of time and so the distribution is the same at all time steps.

This model appears in the correlation matrix and hence can be correlated to any of the other models in the simulation. Use the GaussianRiskDriverIndependent for an equivalent version that does not appear in the correlation matrix.

Input variables

Name	Description
Mean	The mean of the Gaussian distribution of this risk driver, which corresponds to the mean, median and mode if the risk driver is unbounded.
StandardDeviation	The standard deviation of the Gaussian distribution of this risk driver, which corresponds to the standard deviation when the risk driver is unbounded.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the Gaussian distribution with the given mean and standard deviation.

8.3 NormalMeanRevertingRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A normally distributed mean reverting risk driver that is not used in ESG calculations but can be correlated with shocks used within the ESG. This risk driver is a stochastic variable, X, and is modeled according to the stochastic differential equation which describes its evolution over time:

$$dX = \mathrm{Alpha}(\mathrm{Mu} - X)dt + \mathrm{Sigma}\, dZ$$

where dZ is the normally distributed shock for this process, and the remaining elements are described in the following table as input variables.

Input variables

Name	Description
Alpha	The rate of mean reversion of the risk driver process.
Sigma	The volatility of the risk driver process.
Mu	The mean of the risk driver process.
StartVal	The initial value of the risk driver.

Outputs

Name	Description
Value	The instantaneous value of the risk driver at this time step. Calculated according to the following. If Alpha = 0 the Vol = 0, otherwise $Vol = \sqrt{\left(\frac{\mathrm{Sigma}^2}{2\,\mathrm{Alpha}}(1 - \exp(-2\,\mathrm{Alpha}\,\Delta t))\right)}$ and then $\mathrm{Value}(t) = \mathrm{Mu} + \exp(-\mathrm{Alpha}\,\Delta t)(\mathrm{Value}(t-1) - \mathrm{Mu}) + Vol\, dZ(t)$ with Value(0) = StartVal.

Name	Description
Rate	The equivalent annually compounded rate, treating the Value output as a continuously compounded rate. Calculated using the formula: $\mathrm{Rate}(t) = \exp(\mathrm{Value}(t)) - 1$
Index	An index of the risk driver, treating the Value output as a continuously compounded rate. Calculated using the formula: $\mathrm{Index}(t) = \mathrm{Index}(t - \Delta t)\exp(\mathrm{Value}(t)\Delta t)$ where Index(0) = 1.
Change	The relative change in the index of the risk driver rate over the last time interval. $\mathrm{Change}(t) = \frac{\mathrm{Index}(t)}{\mathrm{Index}(t - \Delta t)} - 1$ where Change(0) = 0.

The outputs Index and Change have no economic meaning, these outputs are abstract mathematical functions of the Value output and are available for completeness.

8.4 LogNormalMeanRevertingRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A mean reverting risk driver with lognormal distribution that is not used in Scenario Generator calculations but can be correlated with shocks used within the Scenario Generator. This risk driver is a stochastic variable, X, and is modeled according to the stochastic differential equation which describes its evolution over time:

$$d\ln(X) = \mathrm{Alpha}(\mathrm{Mu} - \ln(X))dt + \mathrm{Sigma}\, dZ,$$

where dZ is the normally distributed shock for this process, and the remaining elements are described in the following table as input variables.

Input variables

Name	Description
Alpha	The rate of mean reversion of the risk driver process.
Sigma	The volatility of the risk driver process.
Mu	The mean reversion level of the logarithm of the risk driver value.
StartVal	The initial value of the risk driver.

Outputs

Name	Description
Value	The instantaneous value of the risk driver at this time step. Calculated according to the following. If Alpha = 0 then Vol = 0, otherwise $Vol = \sqrt{\left(\frac{\text{Sigma}^2}{2\ \text{Alpha}}(1 - \exp(-2\ \text{Alpha}\ \Delta t))\right)}$ and then $\text{Value}(t) = \exp\left[\text{Mu} + \exp(-\text{Alpha}\ \Delta t)(\ln(\text{Value}(t - \Delta t)) - \text{Mu}) + Vol\ dZ(t)\right]$ with Value(0) = StartVal.
Rate	The equivalent annually compounded rate, treating the Value output as a continuously compounded rate. Calculated using the formula: $\text{Rate}(t) = \exp(\text{Value}(t)) - 1$
Index	An index of the risk driver, treating the Value output as a continuously compounded rate. Calculated using the formula: $\text{Index}(t) = \text{Index}(t - \Delta t)\exp(\text{Value}(t)\Delta t)$ where Index(0) = 1.
Change	The relative change in the index of the risk driver rate over the last time interval. $\text{Change}(t) = \frac{\text{Index}(t)}{\text{Index}(t - \Delta t)} - 1$ where Change(0) = 0.

The outputs Index and Change have no economic meaning, these outputs are abstract mathematical functions of the Value output and are available as for completeness.

8.5 SquareRootMeanRevertingRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

A mean reverting risk driver of Cox-Ingersoll-Ross style with square root volatility dependence that is not used in Scenario Generator calculations but can be correlated with shocks used within the Scenario Generator. This risk driver is a stochastic variable, X, and is modeled according to the stochastic differential equation which describes its evolution over time:

$$dX = \text{Alpha}(\text{Mu} - X)dt + \text{Sigma}\sqrt{X}dZ$$

where dZ is the normally distributed shock for this process, and the remaining elements are described in the following table as input variables.

Input variables

Name	Description
Alpha	The rate of mean reversion of the risk driver process.
Sigma	The volatility of the risk driver process.
Mu	The mean of the risk driver process.
StartVal	The initial value of the risk driver.
NumberOfSubdivisions	The number of sub intervals of each time step over which the discretized stochastic process is simulated, effectively using a Brownian bridge to reduce discretization error. If you set this parameter to 1, the Brownian bridge is switched off.

Outputs

Name	Description
Value	The value of the risk driver at this time step. Calculated incrementally according to the following. $\begin{aligned}\text{Value}(t) = {} & \text{Value}(t-1) + \text{Alpha}\,(\text{Mu} - \text{Value}(t-1))\,\Delta t \\ & + \text{Sigma}\sqrt{\text{Value}(t-1)\Delta t}\;dZ(t)\end{aligned}$ with Value(0) = StartVal.
Rate	The equivalent annually compounded rate, treating the Value output as a continuously compounded rate. Calculated using the formula: $\text{Rate}(t) = \exp(\text{Value}(t)) - 1$
Index	An index of the risk driver, treating the Value output as a continuously compounded rate. Calculated using the formula: $\text{Index}(t) = \text{Index}(t-\Delta t)\exp(\text{Value}(t)\Delta t)$ where Index(0) = 1.
Change	The relative change in the index of the risk driver rate over the last time interval. $\text{Change}(t) = \dfrac{\text{Index}(t)}{\text{Index}(t-\Delta t)} - 1$ where Change(0) = 0.

8.6 UniformRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This risk driver produces uniformly distributed samples between specified minimum and maximum values.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Input variables

Name	Description
Min	The lower limit (minimum) of the uniform range of values that this risk driver can take.
Max	The upper limit (maximum) of the uniform range of values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the uniform distribution.

8.7 LogNormalRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This risk driver produces log normally distributed samples, meaning that the logarithm of the samples has a normal (Gaussian distribution). The samples produced from a lognormal distribution can never be negative.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Input variables

Name	Description
Mu	The mean reversion level of the logarithm of the risk driver value.
Sigma	The sigma parameter of a lognormal risk driver is the standard deviation of the log of the values.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the lognormal distribution.

8.8 StudentTRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This risk driver produces samples that have a student t distribution with a given number of degrees of freedom, which can have longer tails than the Gaussian distribution. There is negligible difference between this risk driver and the GaussianRiskDriver when the number of degrees of freedom is larger than about 50. There are also parameters for scaling the distribution to have a particular width and shifting the mean to some non-zero value. This risk driver has no notion of time and so the distribution is the same at all time steps.

Input variables

Name	Description
DegreesOfFreedom	The degrees of freedom of the student t distribution.
Shift	The shift parameter for this risk driver, which corresponds to the mean, median and mode if the risk driver is unbounded.
Scale	The scale parameter for this risk driver. This only corresponds to the standard deviation for high degrees of freedom and when the risk driver is unbounded.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk river at this time step, which is essentially a random sample from the student t distribution with the given scale and shift.

8.9 GeneralisedParetoRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This risk driver has a generalized Pareto distributional form that is often used for modeling decaying values such as tails of distributions, or situations in which most values are small but there are a very small proportion of large values such as some operational risks. It has the following probability density function:

$$PDF(x;\xi,\sigma,\mu) = \begin{cases} \frac{1}{\sigma}\left(1+\frac{\xi\times(x-\mu)}{\sigma}\right)^{-\frac{1}{\xi}-1}, & \xi \neq 0 \\ \frac{1}{\sigma}\exp\left(-\frac{x-\mu}{\sigma}\right), & \xi = 0 \end{cases}$$

This risk driver has no notion of time and so the distribution is the same at all time steps.

Input variables

Name	Description
Xi	The shape parameter for the generalized Pareto distribution.
Sigma	The scale parameter for the generalized Pareto distribution.
Mu	The shift parameter for the generalized Pareto distribution, which is most often set to zero.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the generalized Pareto distribution.

8.10 GeneralisedLambdaRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This risk driver generates samples having a generalized lambda distribution, sometimes known as the asymmetric lambda distribution or as (or being derived from) Tukeys lambda distribution. It is defined in terms of the inverse cumulative distribution, which makes random samples easy to generate. It is popular in some circles due to its "tremendous flexibility" in terms of the shapes that it can take. The most common form and the form that is implemented is as follows:

$$InvCDF\,(p;\lambda_1,\lambda_2,\lambda_3,\lambda_4) = \lambda_1 + \frac{1}{\lambda_2} \times \left(p^{\lambda_3} - (1-p)^{\lambda_4}\right)$$

This risk driver has no notion of time and so the distribution is the same at all time steps.

Input variables

Name	Description
Lambda1	The lambda1 parameter for the generalized lambda distribution is a shift parameter.

Name	Description
Lambda2	The lambda2 parameter for the generalized lambda distribution is a scale parameter.
Lambda3	The lambda3 parameter for the generalized lambda distribution is a left shape parameter.
Lambda4	The lambda4 parameter for the generalized lambda distribution is a right shape parameter.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the generalized lambda distribution.

8.11 EGB2RiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This risk driver generates samples having an exponential generalized beta distribution of the second kind (EGB2). This has the probability density function:

$$PDF(x; m, \phi, p, q) = \frac{\exp\left(\frac{p \times (x-m)}{\phi}\right)}{\phi \times B(p, q) \times \left(1 + \exp\left(\frac{x-m}{\phi}\right)\right)^{p+q}}$$

where $B(p, q)$ is the beta function.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Input variables

Name	Description
M	This is the shift parameter of the EGB2 distribution.
Phi	This is the scale parameter of the EGB2 distribution.
P	This is the (left) shape parameter of the EGB2 distribution.
Q	This is the (right) shape parameter of the EGB2 distribution.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the EGB2 distribution.

8.12 PoissonRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

Risk driver with a Poisson distribution.

Input variables

Name	Description
EventRate	The mean and variance of the Poisson distribution.
Cap	The upper limit for the risk driver value.
Floor	The lower limit for the risk driver value.

Outputs

Name	Description
Value	The value of the risk driver.

8.13 EmpiricalRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	Yes	No

This risk driver is a flexible alternative that can be used when none of the other risk drivers produce a suitably shaped distribution. The distribution is defined empirically using percentiles or as raw data, meaning that it can take on virtually any shape. There is the option of fitting a generalized Pareto functional form to the upper and lower tails of the distribution, and smoothing can be used in the bulk of the distribution to assist in producing smooth continuous distributions from the (necessarily) discrete input data. Defining the distribution using a set of percentiles is the recommended approach as this more closely matches the empirical inverse cumulative distribution function (CDF) format that is used to generate the output.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Input variables

Name	Description
DataFormat	This defines the way in which the input data are specified, either RawData or Percentiles. This enables only one of the PercentileData or RawData inputs.
PercentileData	In this format, specify the data as percentile level and the corresponding percentile value, which allows for input as points on a cumulative distribution function (CDF) or inverse CDF (quantile function). Percentile levels should be strictly increasing and are defined in a proportional sense, meaning that the 95th percentile level would be entered as 0.95. Percentile values should also be ascending but are not required to be strictly ascending.
RawData	In this format, the data is specified as data values with corresponding weights. With different weighting schemes, this allows for input in the form of raw data, histogram, or probability density function (PDF). For equally weighted raw data, set all the weights to 1.0.
SmoothingMethod	This defines the method that is used to smooth the distribution, either linear interpolation or loess which is a local regression smoothing method. Empirical data can only define a discrete distributional representation and the smoothing is used to convert this into a continuous distribution.
SmoothingWindowWidth	This defines the total width of the window that is used by the "loess" smoothing method. The smoothing is performed on the empirical inverse cumulative distribution function, and hence the smoothing window width is defined as a corresponding increment of percentile level, albeit as a proportion, centered on the percentile level of interest. For example, this means that a value of 0.04 would mean that the total window width would be 4%, and so the determination of a percentile level of 25% would take into account all points on the empirical inverse CDF between 0.248 and 0.252.
LowerTailPercentile	The percentile level below which the data points are taken to be in the lower tail. When this parameter is set to a value greater than 0.0, a generalized Pareto functional form is fit to the tail data. When this parameter is set to exactly 0.0, the tail fitting is switched off. The LowerTailPercentile is expressed as a proportion and so for a tail consisting of the lowest 5% of the data/distribution this would be set to 0.05.
UpperTailPercentile	The percentile level above which the data points are taken to be in the upper tail. When this parameter is set to a value less than 1.0, a generalized Pareto functional form is fit to the tail data. When this parameter is set to exactly 1.0, the tail fitting is switched off. The UpperTailPercentile is expressed as a proportion and so for a tail consisting of the largest 3.5% of the data/distribution this would be set to 0.965.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the distribution inferred from the empirical raw data or specified percentiles.

Analysis tests

Name	Description
Empirical Risk Driver Analysis [Granularity]	This analysis test provides information about the empirical inverse cumulative distribution function (CDF) that is used for generating the samples. This reflects smoothing and also tail fitting. The granularity parameter defines the number of intervals over the 0.0 to 1.0 proportional range that is sampled. Details of the generalized Pareto fits (if necessary) to the upper and lower tails are also shown. This included the actual generalized Pareto parameters and also a corresponding Kullback-Leibler (K-L) goodness of fit measure (the smaller the K-L measure the better the fit). Details of the best exponential fit are also shown to demonstrate how far from the exponential distribution the best generalized Pareto fit is. **Note** This analysis test is defined by the input parameters and hence is not dependent on the number of trials or any stochastic shocks used through the simulation.

8.14 GaussianRiskDriverIndependentAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This model can be used to represent a risk factor that has a Gaussian distribution with a specified mean and standard deviation.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

This model is independent of all other models in that it does not appear in the correlation matrix. Use the GaussianRiskDriver for a correlated version.

Input variables

Name	Description
Mean	The mean of the Gaussian distribution of this risk driver, which corresponds to the mean, median and mode if the risk driver is unbounded.
StandardDeviation	The standard deviation of the Gaussian distribution of this risk driver, which corresponds to the standard deviation when the risk driver is unbounded.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the Gaussian distribution with the given mean and standard deviation.
Variate	The standard normal variate underlying the risk driver.

8.15 GaussianRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This model can be used to represent a risk factor that has a Gaussian distribution with a specified mean and standard deviation. This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

This model appears in the correlation matrix and hence can be correlated to any of the other models in the simulation. Use the GaussianRiskDriverIndependent for an equivalent version that does not appear in the correlation matrix.

Input variables

Name	Description
Mean	The mean of the Gaussian distribution of this risk driver, which corresponds to the mean, median and mode if the risk driver is unbounded.
StandardDeviation	The standard deviation of the Gaussian distribution of this risk driver, which corresponds to the standard deviation when the risk driver is unbounded.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the Gaussian distribution with the given mean and standard deviation.

Name	Description
Variate	The standard normal variate underlying the risk driver.

8.16 UniformRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This risk driver produces uniformly distributed samples between specified minimum and maximum values.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014*.

Input variables

Name	Description
Min	The lower limit (minimum) of the uniform range of values that this risk driver can take.
Max	The upper limit (maximum) of the uniform range of values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the uniform distribution.
Variate	The standard normal variate underlying the risk driver.

8.17 LogNormalRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This risk driver produces log normally distributed samples, meaning that the logarithm of the samples has a normal (Gaussian distribution). The samples produced from a lognormal distribution can never be negative.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014*.

Input variables

Name	Description
Mu	The mean reversion level of the logarithm of the risk driver value.
Sigma	The sigma parameter of a lognormal risk driver is the standard deviation of the log of the values.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step, which is essentially a random sample from the lognormal distribution.
Variate	The standard normal variate underlying the risk driver.

8.18 StudentTRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This risk driver produces samples that have a student t distribution with a given number of degrees of freedom, which can have longer tails than the Gaussian distribution. There is negligible difference between this risk driver and the

GaussianRiskDriver when the number of degrees of freedom is larger than about 50. There are also parameters for scaling the distribution to have a particular width and shifting the mean to some non-zero value. This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014*.

Input variables

Name	Description
DegreesOfFreedom	The degrees of freedom of the student t distribution.
Shift	The shift parameter for this risk driver, which corresponds to the mean, median and mode if the risk driver is unbounded.
Scale	The scale parameter for this risk driver. This only corresponds to the standard deviation for high degrees of freedom and when the risk driver is unbounded.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk river at this time step, which is essentially a random sample from the student t distribution with the given scale and shift.
Variate	The standard normal variate underlying the risk driver.

8.19 GammaRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

Risk driver with a gamma distribution.

Input variables

Name	Description
Shape	The shape parameter.
Scale	The scale parameter.
Cap	The upper limit for the risk driver value.
Floor	The lower limit for the risk driver value.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) to include in the standard normal variate underlying this risk driver. If this value is 0, the software uses the entire shock history.

Outputs

Name	Description
Value	The value of the risk driver.
Variate	The standard normal variate underlying the risk driver.

8.20 NonCentralChiSquaredRiskDriver

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

A mean reverting risk driver that produces samples with a non-central chi-squared distribution. This is achieved using a structural model governed by the Cox-Ingersoll-Ross process that has a square root volatility dependence. This means that the process can (in theory) never produce negative values. The risk driver is a stochastic variable, X , and is modeled according to the following stochastic differential equation which describes its evolution over time:

$$dX = \text{Alpha}(\text{Mu} - X)dt + \text{Sigma}\sqrt{X}dZ$$

where dZ is the normally distributed shock for this process, and the remaining elements are described in the following table as input variables.

This SDE is known to produce values for X that are distributed as a non-central chi squared distribution:

$$f(x) = \frac{f_{x^2}\left(\frac{x}{s}, \upsilon, \delta\right)}{s}$$

where v is the number of degrees of freedom, δ is the non-centrality parameter and s is a scalar. The parameters of the non-central chi-squared distribution can be derived from the input parameters at any given time step by the following relations

$$v = \frac{4 \text{ Alpha Mu}}{\text{Sigma}^2}$$

$$\delta = \frac{4 \text{ Alpha } x_0 \exp(-\text{Alpha } t)}{\text{Sigma}^2(1 - \exp(-\text{Alpha } t))}$$

$$s = \frac{\text{Sigma}^2(1 - \exp(-\text{Alpha } t)}{4 \text{ Alpha}}$$

One other interesting thing concerning the shape of this distribution can be noted. The Feller condition says that if:

$$2 \text{ Alpha Mu} > \text{Sigma}^2$$

then the distribution is strictly positive, meaning that the PDF has no weight at zero value. If this is violated, then there can be a significant number of zeros coming through in the scenarios, and potentially a spike in the PDF at zero value.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014.*

Input variables

Name	Description
Alpha	The rate of mean reversion of the Cox-Ingersoll-Ross process.
Sigma	The volatility of the Cox-Ingersoll-Ross process.
Mu	The mean of the Cox-Ingersoll-Ross process.
StartVal	The initial value of the Cox-Ingersoll-Ross process.
NumberOfSubdivisions	The number of sub intervals of each time step over which the discretized stochastic process is simulated, effectively using a Brownian bridge to reduce discretization error. Note that setting this parameter to 1 switches off the Brownian bridge.

Outputs

Name	Description
Value	The value of the risk driver at this time step. Calculated incrementally according to the following: $\text{Value}(t) = \text{Value}(t-1) + \text{Alpha}(\text{Mu} - \text{Value}(t-1))\Delta t + \text{Sigma}\sqrt{\text{Value}(t-1)\Delta t}\, dZ(t)$ with Value(0) = StartVal.

8.21 GeneralisedParetoRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This risk driver has a generalized Pareto distributional form that is often used for modeling decaying values such as tails of distributions, or situations in which most values are small but there are a very small proportion of large values such as some operational risks. It has the following probability density function:

$$PDF(x;\xi,\sigma,\mu)=\begin{cases}\frac{1}{\sigma}\left(1+\frac{\xi\times(x-\mu)}{\sigma}\right)^{-\frac{1}{\xi}-1}, & \xi\neq 0\\ \frac{1}{\sigma}\exp\left(-\frac{x-\mu}{\sigma}\right), & \xi=0\end{cases}$$

This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014*.

Input variables

Name	Description
Xi	The shape parameter for the generalized Pareto distribution.
Sigma	The scale parameter for the generalized Pareto distribution.
Mu	The shift parameter for the generalized Pareto distribution, which is most often set to zero.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the generalized Pareto distribution.
Variate	The standard normal variate underlying the risk driver.

8.22 GeneralisedLambdaRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This risk driver generates samples having a generalized lambda distribution, sometimes known as the asymmetric lambda distribution or as (or being derived from) Tukeys lambda distribution. It is defined in terms of the inverse cumulative distribution, which makes random samples easy to generate. It is popular in some circles due to its "tremendous flexibility" in terms of the shapes that it can take. The most common form and the form that is implemented is as follows.

$$InvCDF\,(p; \lambda_1, \lambda_2, \lambda_3, \lambda_4) = \lambda_1 + \frac{1}{\lambda_2} \times \left(p^{\lambda_3} - (1-p)^{\lambda_4}\right)$$

This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014*.

Input variables

Name	Description
Lambda1	The lambda1 parameter for the generalized lambda distribution is a shift parameter.
Lambda2	The lambda2 parameter for the generalized lambda distribution is a scale parameter.
Lambda3	The lambda3 parameter for the generalized lambda distribution is a left shape parameter.
Lambda4	The lambda4 parameter for the generalized lambda distribution is a right shape parameter.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the generalized lambda distribution.
Variate	The standard normal variate underlying the risk driver.

8.23 EGB2RiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This risk driver generates samples having an exponential generalized beta distribution of the second kind (EGB2). This has the probability density function:

$$PDF(x; m, \phi, p, q) = \frac{\exp\left(\frac{p \times (x-m)}{\phi}\right)}{\phi \times B(p,q) \times \left(1 + \exp\left(\frac{x-m}{\phi}\right)\right)^{p+q}}$$

where $B(p,q)$ is the beta function.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014*.

Input variables

Name	Description
M	This is the shift parameter of the EGB2 distribution.
Phi	This is the scale parameter of the EGB2 distribution.
P	This is the (left) shape parameter of the EGB2 distribution.
Q	This is the (right) shape parameter of the EGB2 distribution.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the EGB2 distribution.
Variate	The standard normal variate underlying the risk driver.

8.24 PoissonRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

Risk driver with a Poisson distribution.

Input variables

Name	Description
EventRate	The mean and variance of the Poisson distribution.
Cap	The upper limit for the risk driver value.
Floor	The lower limit for the risk driver value.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) to include in the standard normal variate underlying this risk driver. If this value is 0, the software uses the entire shock history.

Outputs

Name	Description
Value	The value of the risk driver.
Variate	The standard normal variate underlying the risk driver.

8.25 ParetoCompoundPoissonRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

Risk driver with a Pareto compound Poisson distribution.

Input variables

Name	Description
EventShape	The Type I Pareto shape parameter.
EventMin	The Type I Pareto scale parameter.
EventMax (if UseTruncation is True)	The truncation limit of the Type I Pareto events.

Name	Description
EventRate	The Poisson event rate.
NumberOfSamples	The number of samples to take to build up the CDF.
UseTruncation	Indicates whether to use truncated Type I Pareto events.
Cap	The upper limit for the risk driver value.
Floor	The lower limit for the risk driver value.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) to include in the standard normal variate underlying this risk driver. If this value is 0, the software uses the entire shock history.

Outputs

Name	Description
Value	The value of the risk driver.
Variate	The standard normal variate underlying the risk driver.

8.26 EmpiricalRiskDriverAutoCorrelated

This model is available for the model trees shown in the following table.

	ESG	RSG
Available	No	Yes

This risk driver is a flexible alternative that can be used when none of the other risk drivers produce a suitably shaped distribution. The distribution is defined empirically using percentiles or as raw data, meaning that it can take on virtually any shape. There is the option of fitting a generalized Pareto functional form to the upper and lower tails of the distribution, and smoothing can be used in the bulk of the distribution to assist in producing smooth continuous distributions from the (necessarily) discrete input data. Defining the distribution using a set of percentiles is the recommended approach as this more closely matches the empirical inverse cumulative distribution function (CDF) format that is used to generate the output.

Note This risk driver has no notion of time and so the distribution is the same at all time steps.

Autocorrelated risk drivers are intended for simulating risk factors at a single time horizon, *for example*, one year, in a simulation with either a single time step or multiple shorter time steps. The risk driver is driven by a standard normal variate which is generated as the average of underlying shocks generated over the current and several preceding time steps, up to a maximum determined by the input variable StandardNormalVariateHistory.

For more information, see *David Redfern and Douglas McLean, "Risk Drivers in the B&H Risk Scenario Generator", Moody's Analytics Technical Document, 2014*.

Input variables

Name	Description
DataFormat	This defines the way in which the input data are specified, either RawData or Percentiles. This enables only one of the PercentileData or RawData inputs.
PercentileData	In this format, specify the data as percentile level and the corresponding percentile value, which allows for input as points on a cumulative distribution function (CDF) or inverse CDF (quantile function). Percentile levels should be strictly increasing and are defined in a proportional sense, meaning that the 95th percentile level would be entered as 0.95. Percentile values should also be ascending but are not required to be strictly ascending.
RawData	In this format, the data is specified as data values with corresponding weights. With different weighting schemes, this allows for input in the form of raw data, histogram, or probability density function (PDF). For equally weighted raw data, set all the weights to 1.0.
SmoothingMethod	This defines the method that is used to smooth the distribution, either linear interpolation or loess which is a local regression smoothing method. Empirical data can only define a discrete distributional representation and the smoothing is used to convert this into a continuous distribution.
SmoothingWindowWidth	This defines the total width of the window that is used by the "loess" smoothing method. The smoothing is performed on the empirical inverse cumulative distribution function, and hence the smoothing window width is defined as a corresponding increment of percentile level, albeit as a proportion, centered on the percentile level of interest. For example, this means that a value of 0.04 would mean that the total window width would be 4%, and so the determination of a percentile level of 25% would take into account all points on the empirical inverse CDF between 0.248 and 0.252.
LowerTailPercentile	The percentile level below which the data points are taken to be in the lower tail. When this parameter is set to a value greater than 0.0, a generalized Pareto functional form is fit to the tail data. When this parameter is set to exactly 0.0, the tail fitting is switched off. The LowerTailPercentile is expressed as a proportion and so for a tail consisting of the lowest 5% of the data/distribution this would be set to 0.05.
UpperTailPercentile	The percentile level above which the data points are taken to be in the upper tail. When this parameter is set to a value less than 1.0, a generalized Pareto functional form is fit to the tail data. When this parameter is set to exactly 1.0, the tail fitting is switched off. The UpperTailPercentile is expressed as a proportion and so for a tail consisting of the largest 3.5% of the data/distribution this would be set to 0.965.
Cap	An upper limit on the values that this risk driver can take.
Floor	A lower limit on the values that this risk driver can take.
StandardNormalVariateHistory	The number of shock values (including the current and previous shock values) that you want to include in the standardized normal variate underlying this risk driver. If you want to use the entire shock history, enter 0.

Outputs

Name	Description
Value	The value of the risk driver at this time step. This is essentially a random sample from the distribution inferred from the empirical raw data or specified percentiles.
Variate	The standard normal variate underlying the risk driver.

Analysis tests

Name	Description
Empirical Risk Driver Analysis [Granularity]	This analysis test provides information about the empirical inverse cumulative distribution function (CDF) that is used for generating the samples. This reflects smoothing and also tail fitting. The granularity parameter defines the number of intervals over the 0.0 to 1.0 proportional range that is sampled. Details of the generalized Pareto fits (if necessary) to the upper and lower tails are also shown. This included the actual generalized Pareto parameters and also a corresponding Kullback-Leibler (K-L) goodness of fit measure (the smaller the K-L measure the better the fit). Details of the best exponential fit are also shown to demonstrate how far from the exponential distribution the best generalized Pareto fit is. **Note** This analysis test is defined by the input parameters and hence is not dependent on the number of trials or any stochastic shocks used through the simulation.