

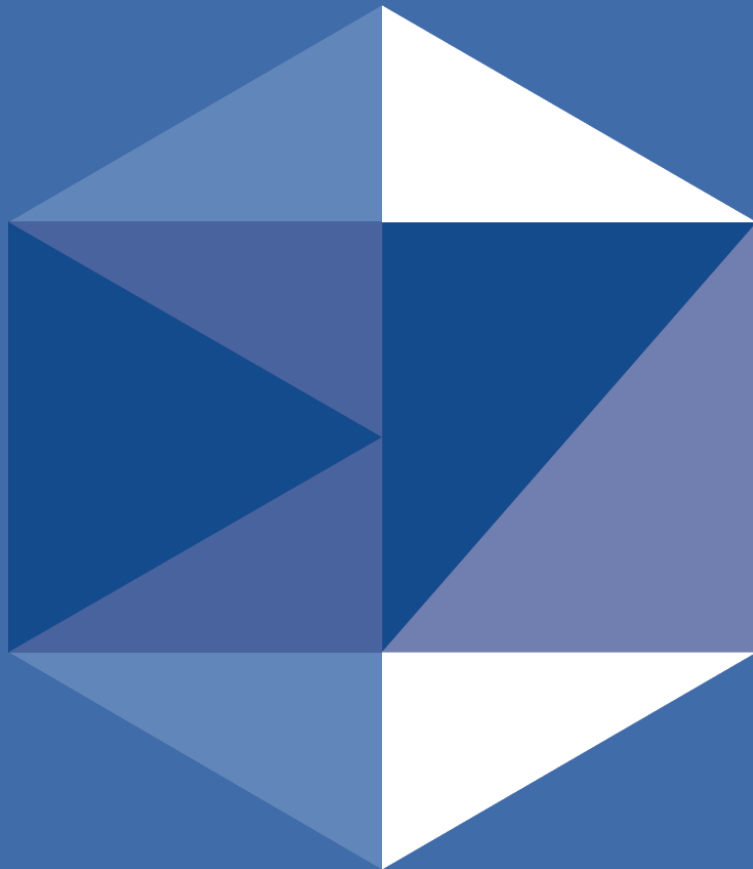


User Manual

Version 2.1

Free educational resource for index investing. Not financial advice. For educational purposes only.

Simplicity is the ultimate sophistication.
Leonardo da Vinci



Contents

1	Introduction	4
2	Indexes Heatmap	6
3	Long-term Performance	9
4	Index Derivative Strategies	11
4.1	Product selection	11
4.2	Basic functions	12
4.3	Payoff charts	13
4.4	Risk charts	13
4.5	Product deep-dive	17
4.6	Product settings pane	17
4.7	Structuring pane	18
4.8	Structuring examples	22
5	Backtester	24
5.1	Backtest settings	24
5.2	Output of backtest	25
5.3	Plot settings	26
6	Technical Appendix	28
6.1	Derived Fixed-Income indexes	28
6.1.1	Indexed performance of savings accounts	28
6.1.2	Total Return Treasury indexes	28
6.2	Derivative Strategy Simulations	29
6.2.1	Pricing of bonds	29
6.2.2	Pricing of options	29
6.3	Literature	33

1 Introduction

Financial indexes have become key instruments to measure the performance of financial markets; at the same time, they serve as underlying for investment products such as funds, Exchange Traded Funds ("ETFs") or derivatives.

Highly relevant financial indexes include well-known equity indexes such as the S&P 500 or the Nikkei 225, exchange rates, commodity prices, treasury yields and central bank rates, which **indexesIQ.com** covers with long term risk and performance analysis functions in the main window:

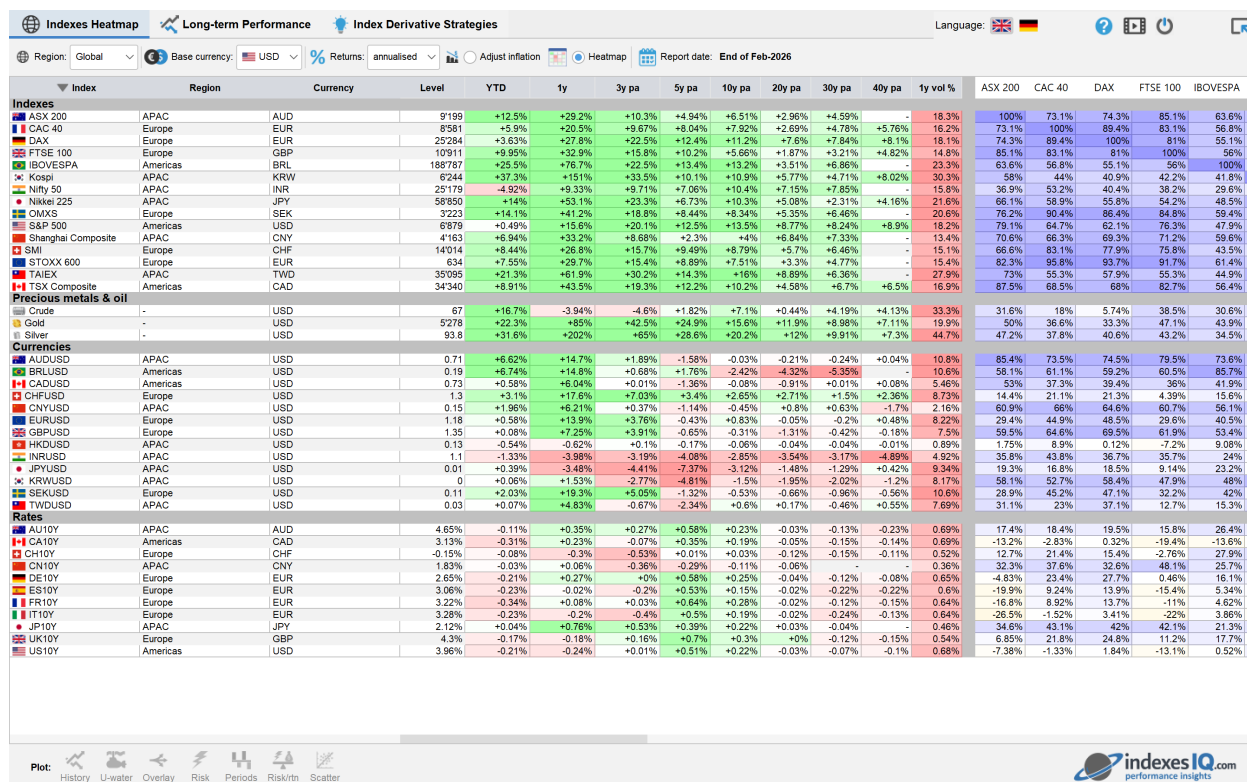


Figure 1.1: Overview of the **indexesIQ.com** application, showing (from left to right) the name, region and currency of indexes, historical performance and volatility as well as a return correlations between indexes.

The website is organized into three panes:

1. **Index Heatmap:** Shows a summary table of global markets performance as well as correlations between markets.
2. **Long-term Performance:** A charting tool to plot long-term risk and return charts.
3. **Index Derivative Strategies:** A simulation tool for long-term derivative strategies including periodic

roll-overs.

At the top of the window, there are several functions shown across all panes:

-  **Language** selection.
-  **Help:** Opens the user manual describing all functions of **indexesIQ.com**.
-  **Tutorial:** Opens a video explaining the main functions of **indexesIQ.com**.
-  Closes the **indexesIQ.com** application.
-  Maximizes the **indexesIQ.com** app within the given window.

2 Indexes Heatmap

The **Indexes Heatmap** pane shows a table with leading global financial indexes covering equities, precious metals, currencies, and treasury yields. The columns of the table show the historical results of the performance, the volatilities and the correlation matrix between different indexes or assets. These financial results are visualized using a heatmap.

At the top of the table, there is a menu bar with the following functions:

 **Region:** Choose a region (Global, North America, EMEA or APAC). The selection of indexes shown in the table is adjusted accordingly. The global region shows the most important indexes globally, while the regional selection shows additional indexes relevant to the chosen region.

 **Base currency:** You can choose between local (every index is shown in its base currency) or a specific currency; in this case, all risk and performance figures will be adjusted to this currency. For instance, if you choose the Euro as currency then the return shown for the S&P 500 will be the return of a Euro investor, i.e. it will include exchange rate risk and performance in the results table.

 **Returns:** can be shown as cumulative returns over the respective period or annualized returns. For interest rates, the returns shown are total changes in interest rates over the respective period or changes per annum.

 **Adjust inflation:** means that all returns and interest rates are adjusted for the inflation of the chosen base currency. For exchange rates, the inflation adjustment is based on the inflation difference between the two currencies. For instance, for the EURUSD exchange rate, the inflation rate of the EUR minus the inflation rate of the USD is taken into account.

 **Heatmap:** You can hide/unhide the heatmap shown in the table.

 **Report date:** You can choose a report date back in time: all financial results shown in the table, including the heatmap, will adjust to the chosen report date.

You can select some rows in the table to plot the time series as shown below:

CHAPTER 2. INDEXES HEATMAP

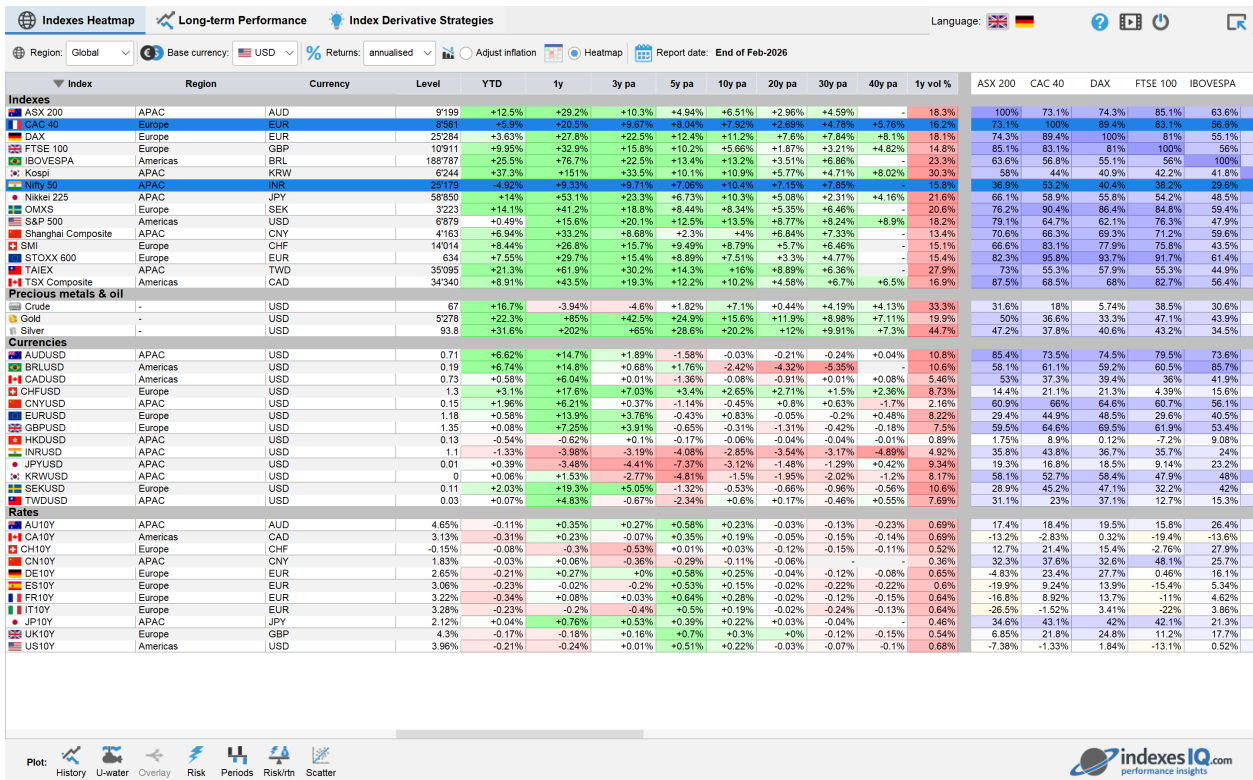


Figure 2.1: Selection of indexes in the main window.

Once some rows have been selected, the **Chart type** menu bar below the table will be enabled with the following plot functions:

- Plot the time series of the index.**
- Plot time series with grey zones indicating international crises or recessions.**
- Plot time series with peak-to-trough return analysis of bull and bear markets (defined as periods with at least $\pm 20\%$ returns in equity markets or $\pm 2\%$ absolute changes in interest rates).**
- Plot the time series including "steps" that indicate for how long an index was going sideways.**
- Plot underwater chart:** This chart shows the draw-down since the last all-time peak over time.
- Plot overlay chart:** Yearly returns including the yearly Max, Min, and most recent performance.
- Plot distribution of percentage returns.**
- Plot histogram of period returns:** Weekly, monthly, quarterly, semi-annual, yearly or bi-yearly returns, depending on the length of the time period.
- Plot the risk-return diagram showing the average yearly volatility and average yearly return.**



Scatter plot of historical returns of the y-axis versus the x-axis.

Once you click on one of these plot functions, the history plot will appear in the **Long-term Performance** pane outlined in the following section.

3 Long-term Performance

The **Long-term performance** pane enables you to look at long-term risk and performance charts. The different plot functions in the menu **Chart type** have already been discussed in the previous section explaining the **Indexes Heatmap** pane.

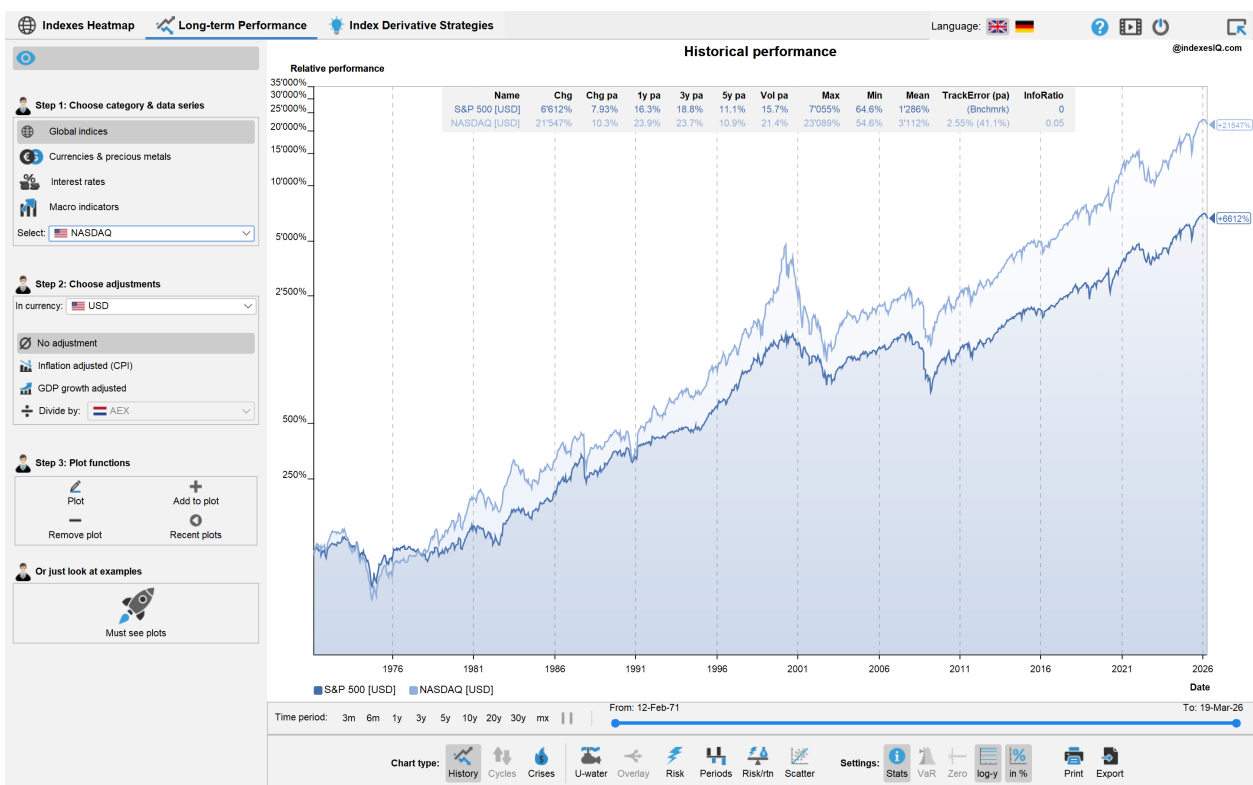


Figure 3.1: Indexes performance chart.

In addition to these plot functions, the **Settings** menu bar below the plot contains the following functions to fine-tune the charts:

-  **Information:** Shows a table containing statistical information of the plotted data sets.
-  **Information:** Shows a pop-up menu that allows you to choose Value-at-Risk options: the time period of returns used (weekly, monthly, quarterly) and the confidence level (90%, 95% or 99%).
-  **Show x-axis:** Set the scale of the y-axis to contain the value $y = 0$.
-  **Y-log:** Set the y-axis to log-scale.
-  **Percent:** Set the y-axis to percentages and re-base all time series to start with 100%.

 **Print or export to** high resolution pdf chart.

 **Export** the data shown in the graph.

On the left hand side of the plot you find a menu bar which you can hide / unhide using the  symbol. In the menu bar you can choose, add or delete time series from the plot in a three step way:

1. **Step 1: Choose category & data series:**

 **Global indices**, covering equity indices, crude oil, as well as fixed-income indices measuring the cumulative return on savings accounts for different currencies.

 **Currencies & precious metals**

 **Interest rates**, covering treasury yields and central bank rates

 **Macro indicators**, covering annual GDP growth rates, cumulative GDP growth, annual consumer price inflation, and CPI (cumulative consumer price indexes).

2. **Step 2: Choose adjustments:**

In currency allows you to plot a series in a different currency. For example, you can plot the S&P 500 in Euro, which means that it is adjusted for the history of the EURUSD exchange rate.

 **Inflation adjusted (CPI)**, which adjusts the time series by the CPI. For equity indexes, this means simply dividing the index series with the CPI of the chosen base currency. For interest rates, this means subtracting the annual inflation rate from the chosen interest rate series. For FX rates, it means adjusting the historical FX time series with the ratio of the CPI of the two currencies.

 **GDP growth-adjusted**, which is calculated by dividing an equity index by the cumulative GDP growth rate of the respective country.

 **Vol history**: You can calculate the historical volatility time series of the chosen time series, calculated over a rolling user-defined time period: 1-y, 2-y or 3-y.

 **Divide (or subtract)**: this allows you to divide one equity series by another series (or subtract an inflation rate or an interest rate from another interest rate series).

 **Combine** with another time series to form a portfolio in constant proportion. For example, you can create a 60/40 portfolio mix of two indexes. In the first menu, you choose the constant proportions; in the second menu you can choose the second asset that matches the chosen currency.

 **Correlate**: You can calculate the historical correlation time series of the chosen time series with another series selected from the menu below, calculated over a rolling user-defined time period: 1-y, 2-y or 3-y.

3. **Step 3: Plot functions:** This is where you actually plot the time series.

 plot **Plot** the chosen time series (in-situ).

 **Add to plot**: adds the chosen time series to the existing plot.

 The **remove plot** function allows you to delete one or several of the time series shown from the plot.

 The **recent plots** function allows you to go back to one of your previous plots.

At the bottom of the menu bar you can also look at a pre-defined set of example plots by clicking on the  symbol.

4 Index Derivative Strategies

The **Index Derivative Strategies** pane allows you to create one or several structured products based on indexes and backtest them over time, including a regular roll-over of the product strategy to make the long-run performance analysis as realistic as possible.

4.1 Product selection

The menu window shown in Figure 4.1 allows you to click through a selection of standard structured products in the tree selection on the left hand side. Each new product you want to create starts by selecting a prototype from this list, which you can then modify. You can switch between different products as explained below.

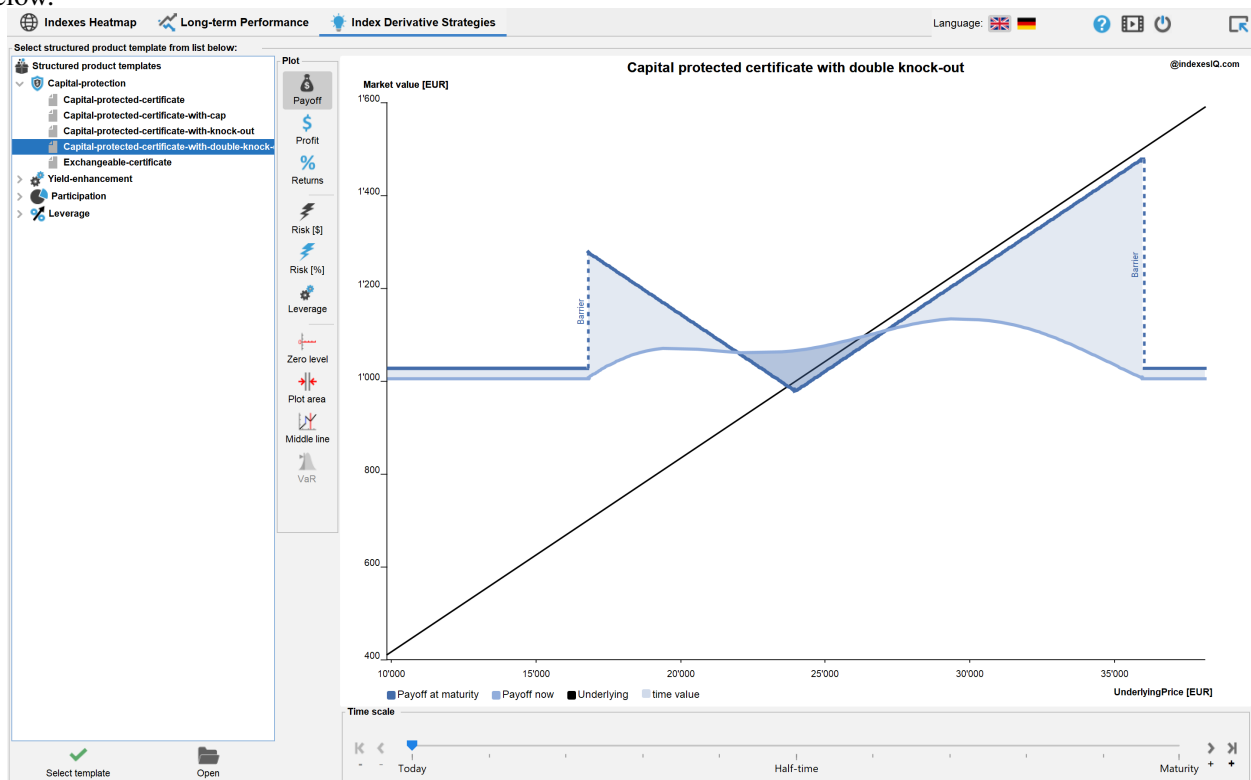


Figure 4.1: On the left hand side you can select a standard product within four product categories – the respective payoff or risk plot appears on the right hand side. The **Select template** function allows you to proceed with a more detailed analysis of the selected product.

The payoff chart for the selected product is shown in the chart on the right. The selection of products is grouped into the four main product categories, shown in increasing order of investment risk:

-  **Capital Protection**
-  **Yield Enhancement**
-  **Participation**
-  **Leverage**

These four categories of structured products are explained in great detail in our afore-mentioned book.

4.2 Basic functions

At the bottom of the window, you have the following functions:

-  **Select template:** allows you to drill-down into the product details of the selected product template (s. section **Product settings pane** below).
-  **Details** allows you to look at existing products in your portfolio. If there are no existing products, the **Open** button will appear instead.
-  **Open:** You can load structured products from an external file that was saved previously, provided there are no products in your portfolio. Otherwise, the **Detail** button will appear instead.

Once you have selected a product, the window changes, and the **Select template** button is replaced with two new buttons:

-  **Product menu**, which takes you back to the initial window.
-  **Delete** the current product template. After deletion, the window will show the previous product in the product portfolio or (if no other product exists) returns to the product menu.
-  **Backtest**, which opens the backtest window to run historical backtests for the chosen product (see the following section).
-  **Save** your current portfolio with structured products.
-  **Save as:** Allows you to save the existing product(s) to a new file.
-  **Close** your current portfolio of structured products (only enabled if changes have been saved). Afterwards, you can create new products from the product menu.
-  This button allows you to change the name of the product.

There are two additional functions in the menu below the chart:

1. **Product:** Shows the menu of existing structured products in your portfolio and allows you to switch between them.
2. The **time scale** function allows you to choose a time point between the issuance date and the maturity date of the product. The payoff plot or risk plot automatically adjusts to the chosen point in time.

4.3 Payoff charts

Next to the payoff chart, you see a selection of plotting functions for the selected product:

- 💰 Sets the graph to show the **payoff (=market value)** of the structured product as a function of the underlying asset price.
- 💵 Sets the graph to show the **profit and loss** of the structured product as a function of the underlying asset price.
- % Sets the graph to show the **return on investment in %** of the structured product as a function of the underlying asset price.

In order to understand these three different plots conceptually, we take a look at a standard call option on a given asset, which the investor purchases on the issuance date for the option premium p_c . At maturity, we have

$$\text{Payoff} = \text{Max}(\text{Asset price} - \text{Strike}, 0)$$

$$\text{Profit} = \text{Max}(\text{Asset price} - \text{Strike}, 0) - p_c$$

$$\text{Return} = 100\% \times \frac{\text{Profit}}{p_c}$$

The resulting plots for these three quantities are illustrated in Figure 4.2, which are essentially the three types of financial performance charts you can choose to plot.

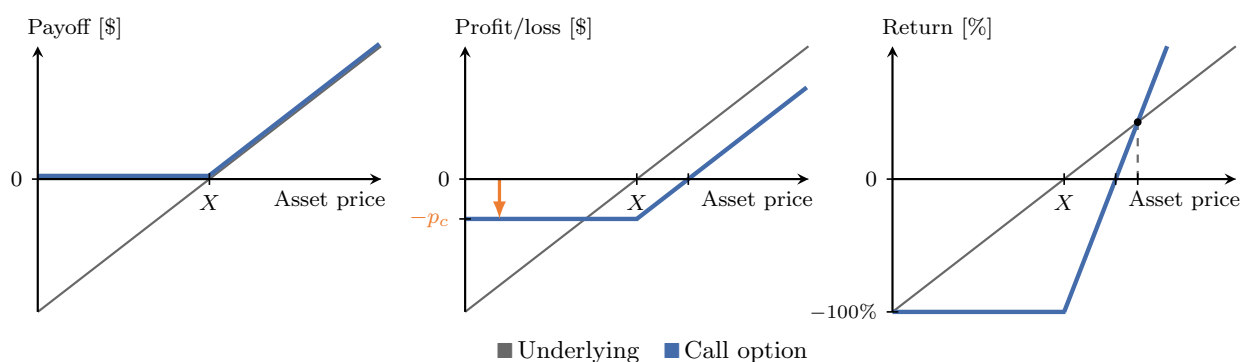


Figure 4.2: Payoff, profit/loss and return of a call option.

4.4 Risk charts

In addition to the performance related plots, there are three risk related plotting functions:

- ⚡ Shows the **historical return distribution and the Value-at-Risk** of the structured product in currency units based on a complete historical simulation of all relevant risk factors.
- ⚡ Shows the **historical return distribution and the Value-at-Risk in percent of the current market value** of the product, based on a historical simulation of all relevant risk factors.
- ⚙ Shows the **leverage ratio** of the structured product, which is defined as the price change of the structured product in percent per price change of the underlying in percent.

The first two of these graphs refer to the probability distribution for the product's performance, which can be measured based either on profits or on returns as illustrated in Figure 4.3. The latter plot helps you assess the degree of leverage: the distribution of returns for the call option is clearly broader than for the underlying asset.

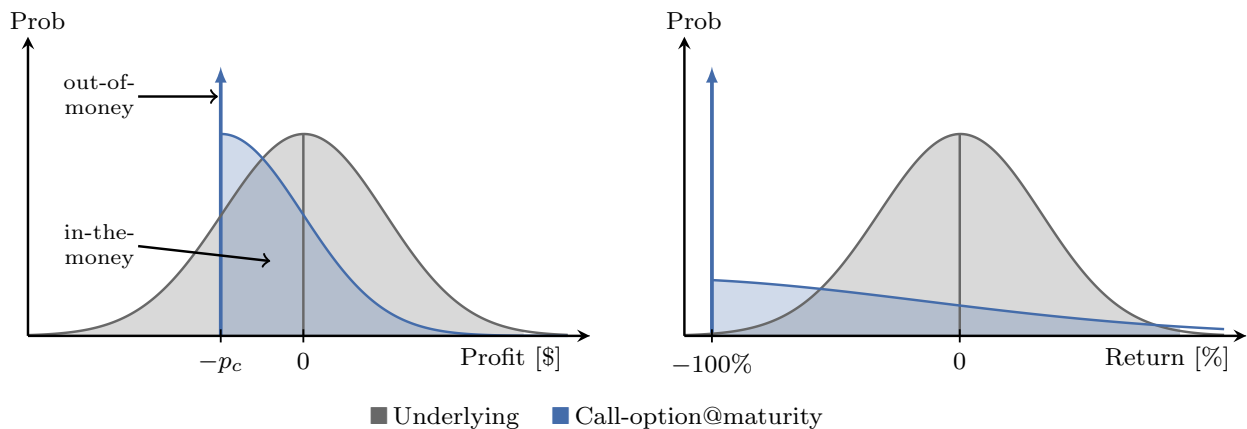


Figure 4.3: Probability distributions for profits and losses (left) and for returns (right) for a call option.

An alternative way to assess the riskiness of a product is to plot the degree of leverage ("leverage ratio"), which is defined as the product's percentage change in value ($\Delta \text{Product value} / \text{Product value}$) per percentage change in the value of the underlying $\Delta \text{Asset price} / \text{Asset price}$. For our exemplary call option this means:

$$\text{Leverage ratio} = \frac{\frac{\Delta \text{Product value}}{\text{Product value}}}{\frac{\Delta \text{Asset price}}{\text{Asset price}}} = \frac{\frac{\Delta \text{Max}(\text{Asset price} - \text{Strike}, 0)}{P_c}}{\frac{\Delta \text{Asset price}}{\text{Asset price}}}$$

Figure 4.4 shows an example of the product leverage plot for the double knock-out capital certificate, which has two barriers. At each barrier, the leverage plot shows a discontinuity.

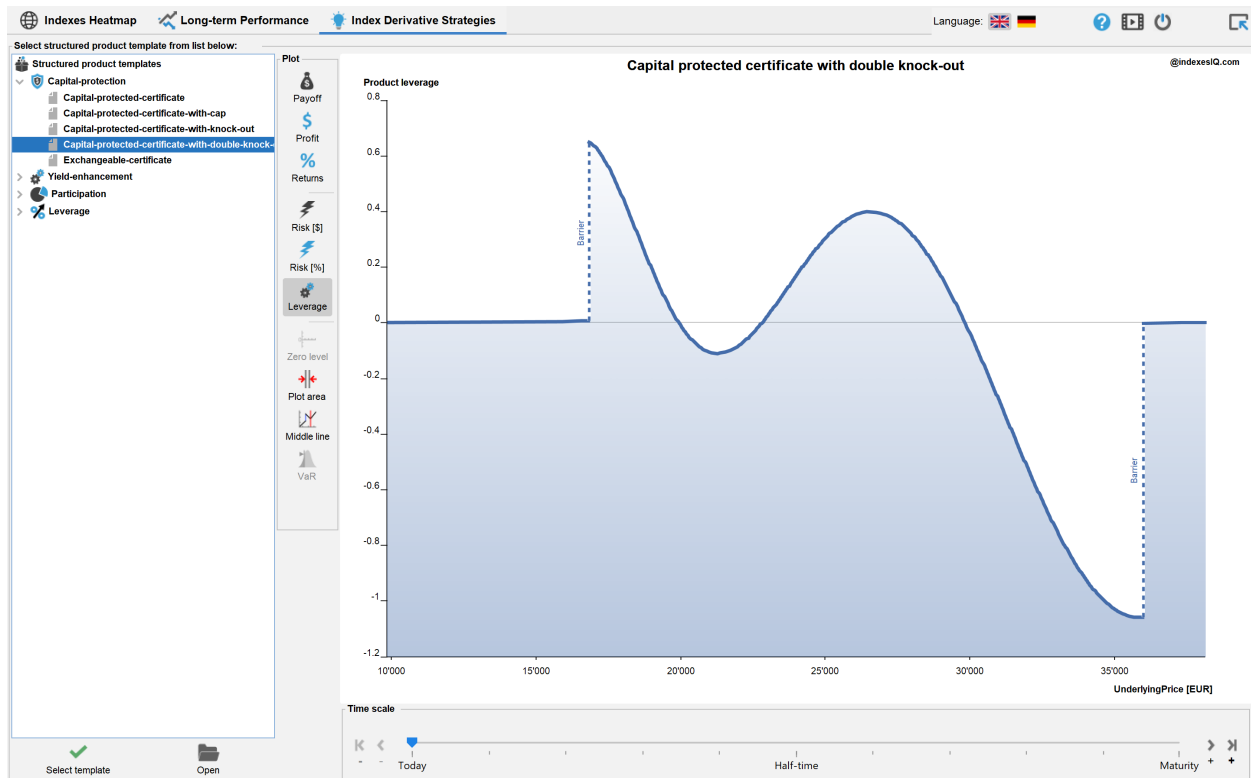


Figure 4.4: Example of leverage plot for a capital protected certificate with double knock-out.

As the example illustrates, the leverage of a structured product can change significantly when the price of the underlying asset changes.

Finally, there are some important plot options to fine-tune the different payoff and risk charts:

-  Sets the **minimum of the y-axis** to zero (if positive, otherwise it is disabled).
-  Shows the **initial underlying price level** as a vertical line in the chart.
-  Allows you to change the plot area (= range of the underlying price) of the payoff chart.
-  Allows you to change the holding period, confidence level and granularity of the **Value-at-Risk** chart, as well as the options of the plot (display of the interpolated distribution functions, labels for strike and barriers, as well as the probability estimates for the different sections of the distribution) as shown in Figure 4.5.

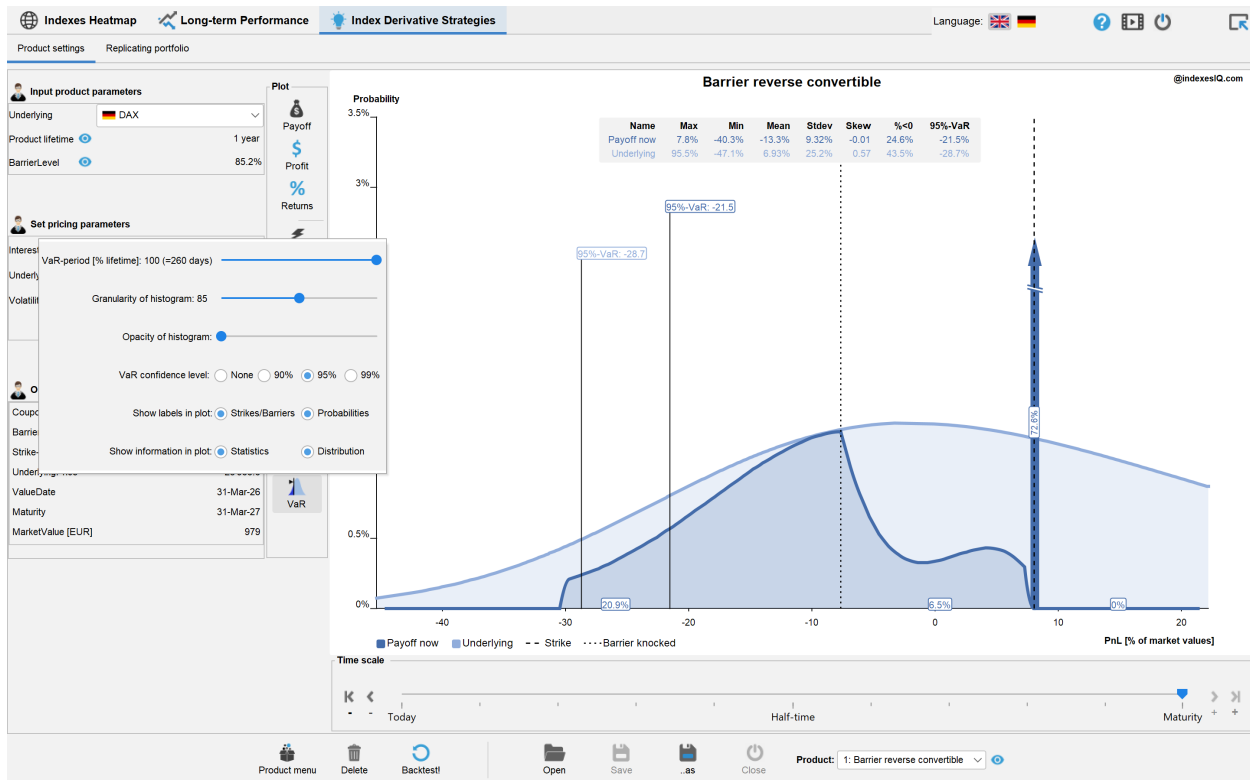


Figure 4.5: Risk plot with the pop-up menu to change the Value-at-Risk parameters, granularity and opacity of the histogram as well as the labels and interpolated probability distribution shown.

It is important to highlight that the probability distribution of returns changes during a product's lifetime, which you can simulate using the afore-mentioned time-scale function.

For example, figure 4.6 shows the return distribution of a reverse convertible and how it changes over time from issuance to maturity for a given holding period. At issuance, the distribution is smooth, while at maturity, the probability distribution shows a spike, indicating the discrete probability of the capped upside.

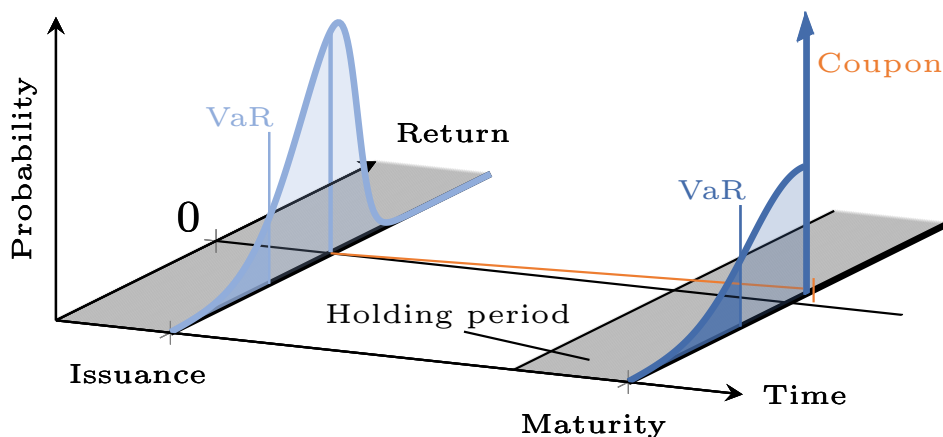


Figure 4.6: Sketch of the return probability distribution of a reverse convertible and its change over time. The grey area shows the holding period. The orange line shows how the product accrues the coupon over time, which is paid at maturity. The probability spike shows the discrete probability of receiving the coupon at maturity as return.

You can change the holding period of the simulation as percentage of the product's lifetime using the menu shown in figure 4.5 above.

4.5 Product deep-dive

After selecting a structured product, the main window shows two panes:

- **Products settings pane:** In this area, you can change the basic product parameters of the product such as time to maturity, strikes etc. as well as change the market price parameters of the product.
- **Structuring pane:** In this area, you can define the replicating portfolio of a structured product and the related replication rules. These functions are for advanced users who are familiar with the replication rules of structured products.

Both panes are described in detail in the following sections.

4.6 Product settings pane

The **product settings panel** shown in Figure 4.7 contains basic parameters of the structured product that can be easily modified, even by inexperienced users. On the left hand side there are three areas:

In the **Input product parameters** area you can change product parameters such as the **lifetime** of the product in years or the strike and barrier levels in % of the underlying price at issuance. To change a specific parameter, you can click on the respective symbol  next to the parameter name, which will open a pop-up scroll bar to change the parameter. The feasible range of parameter values is defined in the rule modeller described below.

One important input is the underlying asset: the menu offers a range of indexes such as the S&P 500, EuroStoxx 50, DAX etc. The choice is important for two reasons: Firstly, the market pricing parameters (see next paragraph) such as the expected return and volatility of the underlying asset are set to the long-term averages of the respective index. Secondly, you can backtest a structured product's performance in the **Backtester** described below. The backtested performance will obviously depend on the performance of the underlying index.

In the **Set pricing parameters** area you can change market price parameters such as the level of interest rates or the volatility of the underlying asset. The standard setting for the volatility and expected return of the underlying asset are set to the long-term averages of the chosen underlying asset. You can modify these values by using the respective scroll bars.

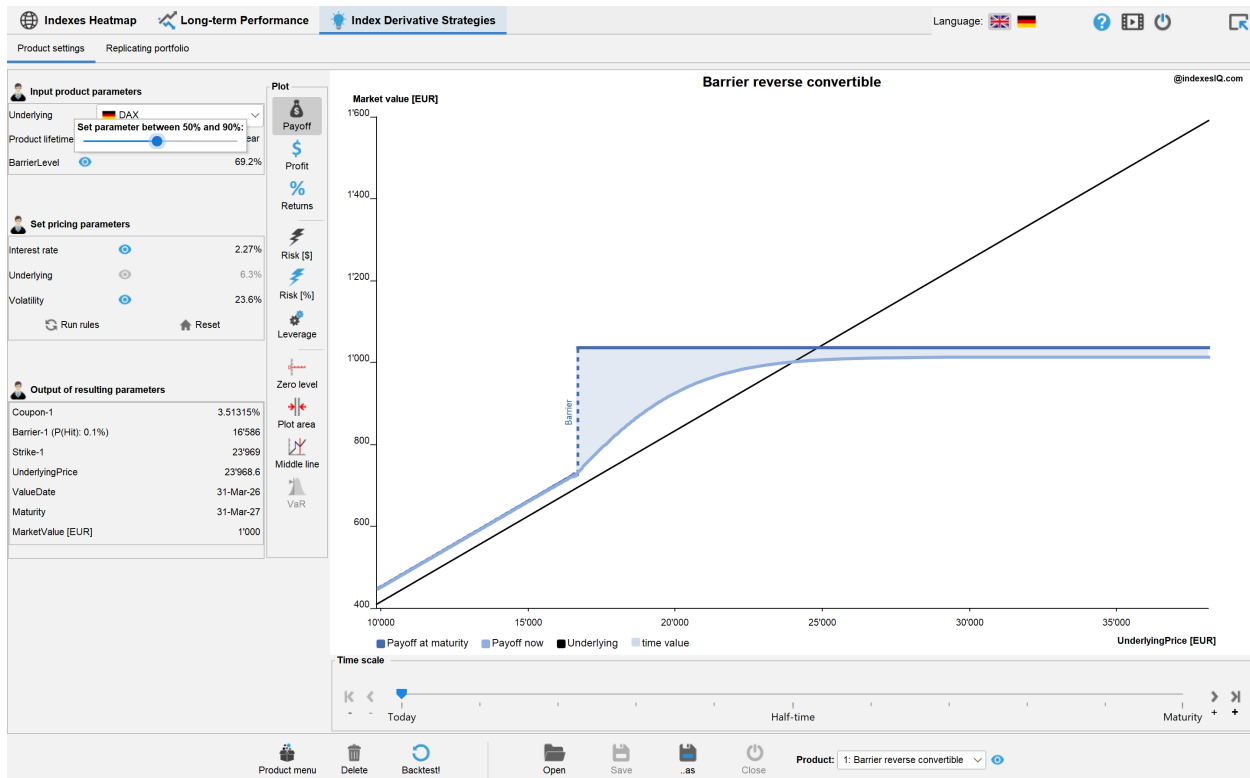


Figure 4.7: Product settings pane where you can change both product parameters and market price parameters.

In the **Output of resulting parameters** area the calculated product parameters (such as actual strike levels, maturity date, product price, Value-at-Risk) are shown. The **ValueDate** and **Maturity** indicate the lifetime of the product. Any change in one of the product parameters or market parameters will automatically lead to a re-calculation of all product outputs, including the product plot on the right hand side.

In addition, there are two buttons within the area for setting pricing parameters:

 **Run rules:** Runs the structuring rules defined in the rule modeller (see **Structuring pane** below). This will mean that changes in market price parameters such as interest rate or volatility will be taken into account in the product design at issuance.

 **Reset:** Reset all market parameters to their initial values.

4.7 Structuring pane

The **structuring pane** shown in Figure 4.8 is for experts, who want to use advanced modelling techniques to create new structured products instead of using existing product templates only. Each structured product is modelled by a replicating portfolio of basic investment instruments and structuring rules that define all

parameters of these instruments as a function of the desired product characteristics.

Position table (This is where you define the product's replicating portfolio)

#	Description	Number	Notional	Coupon	Strike	Barrier	Rebate	MTM-Price
Pos1	(Long) ZeroBond 31-Mar-27		977.82					97.782%
Pos2	(Long) Call Up-knock-out Barrier 23'969 DAX 31-Mar-27	0.0417			23'969	35'953	1'198.4	1'565.6
Pos3	(Long) Put Down-knock-out Barrier 23'969 DAX 31-Mar-27	0.0417			23'969	16'778	1'198.4	1'031.8

Rule table (This is where you define the product's composition rules)

Variable	=Function() at TradeDate	Parameter=value/min/max	Explanation
Pos1Notional	ProductNotional*Pos1MTM-Price		Bond pays product notional at maturity
Pos2Strike	UnderlyingPrice		Strike at the money
Pos2Number	Participation*ProductNotional/UnderlyingPrice	Participation=100% 60% 150%	Set upside participation
Pos2Barrier	UpKnockOutLevel*UnderlyingPrice	UpKnockOutLevel=150% 120% 180%	Set upside knock-out level
Pos2Rebate	UpRebateRate*UnderlyingPrice	UpRebateRate=5% 0% 50%	Set upside rebate
Pos3Number	Pos2Number		Downside participation same as upside participation
Pos3Strike	Pos2Strike		Same strike
Pos3Barrier	DownKnockOutLevel*UnderlyingPrice	DownKnockOutLevel=70% 50% 90%	Set downside knock-out level
Pos3Rebate	Pos2Rebate		Set downside rebate

Solve constraint: Initial value = for variable:

Product: 2: Capital protected certificate with double knock-out

Figure 4.8: Structuring pane: The upper table contains the replicating positions of the product whereas the lower table is used to define the structuring rules.

Therefore, the **structuring pane** contains two tables which are used for the structuring process:

1. The **position table** above: Shows the positions that make up the structured product (= the replicating portfolio), which are numbered Pos1, Pos2... in the first column of the table. The **position table** contains the following standard functions that can be used to amend or change the composition of the replicating portfolio of the structured product:



New position: Opens the **TradeManager** to create new positions as shown in Figure 4.9.

Figure 4.9: Trade Manager to enter new position or modify existing position.

You can modify existing positions by double clicking on them in the position table, which will open the **TradeManager**. In this case, position attributes that are defined by user-defined rules in the rules tables using other positions' attributes cannot be changed in the **TradeManager** as shown in the example in Figure 4.10.

Figure 4.10: Modify existing positions: only attributes not defined by user-defined rules can be modified.

-  **Remove** selected positions.
-  **Copy** selected positions into the clipboard.
-  **Paste** clipboard into the portfolio.

2. The **rule table** below contains rules defining the basic position parameters for all positions within the structured product such as product notional, strike, barrier, etc. The rule table contains four columns:
 - a) The first column indicates the variable that is defined by the rule, e.g. "Pos1!Strike" is the strike price of the instrument called "Pos1".

- b) The second column contains the formula that is used to calculate the variable chosen in column one at **ValueDate**.
- c) In the third column, you can define the product parameters (see below).
- d) In the fourth column, you can enter a comment explaining the calculation rule.

The rules are managed by the following functions:

-  **New rule:** Opens the formula editor to enter a new rule.
-  **Define the parameter** as shown in Figure 4.11, using the input format:
parameter name = initial value | minimum | maximum value

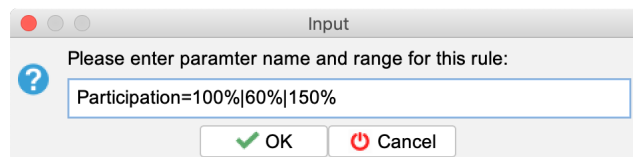


Figure 4.11: Example showing how to define the new parameter *Participation* with initial value 100%, minimum value 60% and maximum value 150%.

Once the parameter has been defined it will appear as an additional parameter you can adjust in the **Product settings pane**. For example, the parameter "Participation" defined in Figure 4.11 appears in the **Input product parameters** section in Figure 4.7.

-  **Add comment** to explain a rule or parameter as shown in Figure 4.12.

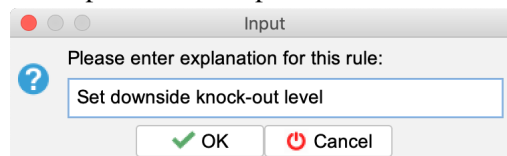


Figure 4.12: Example of a comment explaining a rule in the rule table.

Each rule is entered in the form of a position variable of one of the positions of the product that is defined as a function of other position variables evaluated at **ValueDate**, i.e., the date the rules are evaluated. Both the dependent variable and the formula, which is evaluated as of **ValueDate**, are entered into the formula editor illustrated in Figure 4.13 that opens when you click the *New rule button* or double click an existing rule in the rule table.

In general, variables are named after the position number and the respective position parameter, joined by an exclamation mark. For example, if the second position is an option, then the value of its strike is called **Pos2!Strike**. The dependent variables you can define by using a rule are as follows:

For positions based on the underlying asset:

- Number of underlying
- Strike
- Barrier

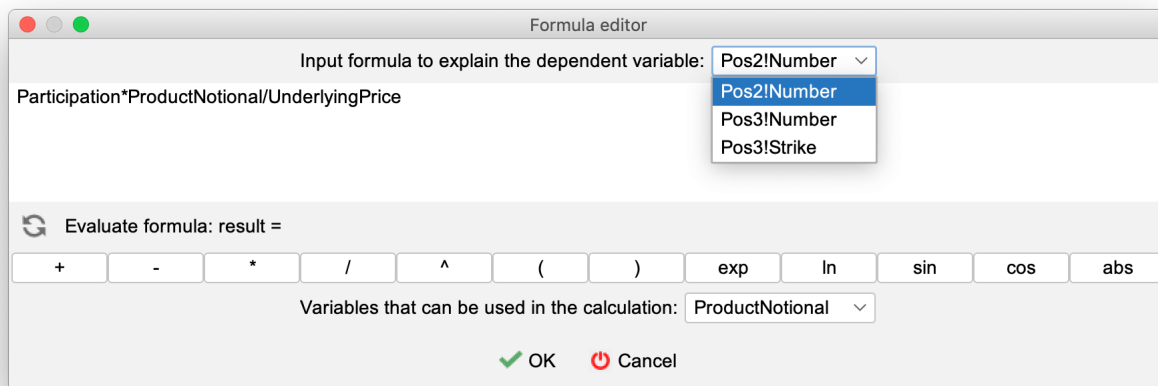


Figure 4.13: Formula editor to enter the dependent variable (menu on the upper right) as a function of other position variables chosen from the menu on the lower right. You can evaluate the formula using the Result button.

- Rebate

For positions in Fixed-Income:

- Notional amount
- Coupon

The input variables that can be used in the defining function are the following:

- All of the above parameters, which can be used as dependent variables
- The price of the underlying
- The product notional

The rule table also contains an input bar to enter a construction constraint, where the initial value of the entire product (i.e., the value at **ValueDate**) is solved for the chosen variable to equal the amount defined by the function entered by the user. For example, the strike of an option can be chosen so that the market value of the structured product is equal to a predefined value at **ValueDate**.

4.8 Structuring examples

Let us look at a specific example: you want to create a capital protected note using a zero-bond (=Pos1) and a call option (=Pos2), which can be entered using the **TradeManager**. The key challenge is to define the contract size of the bond and the option in line with the product notional (=size of the underlying asset) and to set the call's strike level.

Therefore, we define rules that are evaluated on the date of issuance of the product. At that time, the price of the zero-bond is **Pos1!MTM-Price**, the price of the underlying asset is **UnderlyingPrice**, and the product's notional is **ProductNotional**. In addition, we want to define a flexible Participation in the form of a parameter, which we input for the call option using the afore-mentioned parameter function to set the parameter to **Participation = 80%|60%|120%**, i.e. an initial value of 80% and a feasible range between 60% and 120%.

Afterwards, we can enter the size of the bond to ensure the bond pays the **ProductNotional** at maturity, i.e. we add the rule:

$$\text{Pos1!Notional} = \text{ProductNotional} \times \text{Pos1!MTM-Price}$$

Next, we set the strike of the option at the money using the following rule, evaluated at issuance:

$$\text{Pos2!Strike} = \text{UnderlyingPrice}$$

And the number of underlyings of the option is defined to fit the **ProductNotional** $\times$ **Participation** at issuance with the following rule:

$$\text{Pos2!Number} = \text{Participation} \times \text{ProductNotional} / \text{UnderlyingPrice}$$

In addition, we can add comments to each rule as explained above. In the end, we see the following set of positions, parameters, and rules defining our capital protected certificate as shown in Figure 4.14.

The screenshot shows the 'Index Derivative Strategies' interface. At the top, there are tabs for 'Indexes Heatmap', 'Long-term Performance', and 'Index Derivative Strategies'. The 'Index Derivative Strategies' tab is active. Below the tabs, there are 'Product settings' and 'Replicating portfolio' sections. The main area is divided into two tables: 'Position table' and 'Rule table'.

Position table (This is where you define the product's replicating portfolio)

#	Description	Number	Notional	Coupon	Strike	Barrier	Rebate	MTM-Price
Pos1	0% (Long) ZeroBond 31-Mar-27		977.82					97.782%
Pos2	Call European 23'969 DAX 31-Mar-27	0.0335			23'969			1'623

Rule table (This is where you define the product's composition rules)

Define: Product notional = 1000 at TradeDate

Variable	=Function() at TradeDate	Parameter=value min max	Explanation
Pos1!Notional	ProductNotional*Pos1!MTM-Price		Bond pays product notional at maturity
Pos2!Strike	UnderlyingPrice		Strike at the money
Pos2!Number	Participation*ProductNotional/UnderlyingPrice	Participation=80.4% 60% 120%	Set participation

Solve constraint: Initial value = for variable: Product: 1: Capital protected certificate

Figure 4.14: Set of positions and rules to define a capital protected certificate.

5 Backtester

The **Backtester** allows you to backtest the value and risk profile (=Value-at-Risk) of a structured product over longer periods of time, using weekly re-valuations going back in time.

In addition, you can perform advanced backtests, which include a frequent roll-over strategy of the underlying product. You can simulate investment strategies that invest into a structured product; when the product matures, the pay-off is rolled over into a new structured product of the same type with the same lifetime. Therefore, it is important to reset key parameters of the structured product such as the maturity, the strike, the barrier, or the contract size of options at each roll-over, using the afore-mentioned replication rules in the rule modeller. In essence, this is the most realistic way of backtesting long-term investment strategies in a given structured product.

5.1 Backtest settings

In the menu bar of the **Backtester**, you can choose the following settings:



Set period: Enter time period of the backtest.



Set strategy: The strategy menu is a key function of the **Backtester** and allows you to define the underlying strategy for rolling the pay-off from one structured product to the next product, using the following menu:

Set roll-over strategy for backtesting

Roll-over period for backtest

☐ Quartlerly roll-over

☒ Yearly roll-over

☐ Biennial roll-over

(Number of roll-overs capped at 20!)

Figure 5.1: *Backtest strategy menu.*

Within the strategy menu, you can choose:

- **Quarterly roll-over:** uses a quarterly roll-over into a new product.
- **Yearly roll-over:** uses a yearly roll-over into a new product.
- **Biennial roll-over:** uses a biennial roll-over into a new product.

During the backtest of a product the composition rules are re-run at each roll-over to calculate the values of barriers, strikes etc. In essence, this function allows the user to simulate a rolling investment strategy in a given structured product.

It is important to mention that the backtest including roll-overs begins in the past with the current product value (i.e. the backtest shows the evolution of the strategy if the investor had invested today's value into the corresponding product at the beginning of the backtesting period) and typically ends with a product value that can be quite different from the current value.

5.2 Output of backtest

Once you have defined the time period and strategy for the backtest, they can continue with the following functions in the menu:

 **Backtest!:** Run the historical backtest and display the result in the plot window.

Afterwards, the **Show** menu allows you to choose between four different plots to view the results:

1. Historical performance of the market value of the product and its VaR over time.
2. Compare the historical market value of the product to the value of the underlying.
3. Evolution of the ratio (VaR / market value of the product) over time. This plot can be used to assess the development of the relative riskiness of the product over time.
4. Evolution of the weekly profits and losses (based on a buy and hold assumption) versus the respective previous-week VaR, which can be used to backtest the confidence level of the VaR methodology.

If you backtest a structured product that contains barrier options, the barrier hits that occur within the backtest are shown in the plot by a  sign.

The roll-over dates in the backtest are indicated by blue lines along the x-axis, as shown in the figure below.



Figure 5.2: Backtest of a structured product with yearly roll-over / re-run of structured products rules compared to the underlying benchmark index of the product. Barrier hits of the product are indicated in the backtest plot of the product. Blue lines on the x-axis indicate roll-over dates.

5.3 Plot settings

The **Plot menu bar** contains the following functions:

-  **Plot time series of the backtest.**
-  **Plot time series with **peak-to-trough return analysis** of bull and bear markets (defined as periods with at least $\pm 20\%$ returns).**
-  **Plot underwater chart:** This chart shows the draw-down since the last all-time peak over time.
-  **Plot distribution of percentage returns.**
-  **Plot histogram of period returns:** Weekly, monthly, quarterly, semi-annual, yearly or bi-yearly returns, depending on the length of the time period.
-  **Plot risk-return diagram** showing the average yearly volatility and yearly return.
-  **Scatter plot** of historical returns of the product versus the underlying asset.

The **Settings menu bar** contains the following functions:

 **Information:** Shows a table containing statistical information of the plotted data sets.

 **Show x-axis:** Set the scale of the y-axis to contain the value $y = 0$.

 **Y-log:** Set the y-axis to log scale.

 **Percent:** Set the y-axis to percentages and re-base all time series to start with 100%.

6 Technical Appendix

The appendix provides the technical details of the calculations in the **indexesIQ.com** app.

6.1 Derived Fixed-Income indexes

The **indexesIQ.com** app uses time series of central bank rates and 2-year and 10-year treasury rates for different currencies as input, which can be plotted in the app. In addition, two derived time series are created and can be plotted in the app:

6.1.1 Indexed performance of savings accounts

The **indexesIQ.com** app shows benchmarks for average savings account performance in different currencies called Cash-USD+%, Cash-EUR+% etc.

These indexes can be plotted or used as benchmarks versus other assets. Average savings rates are hardly observable in the market; therefore, we use the following proxy derived from academic literature, which estimates the average savings rate AS_t as a combination of central bank rates CBR_t and 2-year treasury yields $TR2Y_t$:

$$AS_t = \text{Max}[5bps, 0.7 \times (CBR_t - 75bps) + 0.3 \times TR2Y_t] \quad (6.1)$$

This calculation of the average savings account interest rate is a practitioner simplification consistent with the empirical literature on deposit rate pass-through (Drechsler, Savov and Schnabl 2017; Polo 2021; IMF WP 2024/009), which consistently finds deposit betas below 1, asymmetric adjustment, and compressed pass-through near the zero lower bound.

The actual total return index is then simply accruing the savings rate over time. The so-called Cash+% time series in the app is calculated as

$$\text{Cash}+\%(t + \Delta t) = \text{Cash}+\%(t) \times (1 + \Delta t \times AS_t) \quad (6.2)$$

where Δt is measured in fractions of years. The savings rate AS_t is updated monthly.

6.1.2 Total Return Treasury indexes

indexesIQ.com calculates the total return indexes that replicate the performance of a portfolio that invests in treasuries at constant maturity. Technically speaking, the index methodology assumes that at each monthly re-balancing the index value is invested in a par treasury bond of maturity M at the prevailing yield.

During the following month, the index value is calculated as the "dirty" price (i.e., the price including accrued interest) of the bond, using the ISMA bond price formula described below and using the treasury yield y_t at each point in time. At the next monthly re-balancing, the bond is sold at the dirty price and

re-invested in a new treasury par bond at maturity M .

These total return indexes are named using the respective two-letter country symbol and maturity with the suffix "TR". For example, the total return index tracking 10Y US Treasuries is called the "US10Y TR" index.

6.2 Derivative Strategy Simulations

The technically most complex area of the app is the simulations of derivative strategies, which is entirely based on the well-known Black & Scholes framework, as well as standard pricing formulas for the bond components of structured products summarized below.

6.2.1 Pricing of bonds

The bond price used is the clean price calculated according to the well-known ISMA (former AIBD) formula:

$$P = \frac{1}{(1+y/f)^{N+t}} + \sum_{i=1}^N \frac{c/f}{(1+y/f)^{i+t}} - (1-t)c/f \quad (6.3)$$

With:

- P = **MTM-price** = clean price of the bond
- N = number of outstanding coupon payments
- c = **Coupon** in % p.a.
- f = **Frequency** = coupon frequency in times per annum
- y = **CurrentYield** = applicable yield to maturity in % p.a.
- t = time till next coupon payment as fraction of the coupon period

The accrued interest **Accrual** = $(1-t)c/f$ of the bond within a structured product is accrued throughout the product's lifetime. For instance, when you use the time machine function in the derivative window, the value of the product will increase with the accrued interest.

6.2.2 Pricing of options

The price of options is calculated using continuous compounding in the short rate and dividend yield, based on standard-formulas:

- For **European and Asian options**: Black & Scholes formula:

Let

$$d_1 = \frac{\ln(S/X) + (r - q - \sigma^2/2)T}{\sigma\sqrt{T}}, d_2 = d_1 - \sigma\sqrt{T}$$

Then the call price C_{BS} and the put price P_{BS} in the Black and Scholes (BS) read:

$$C_{BS} = Se^{-qT}N(d_1) - Xe^{-rT}N(d_2) \quad (6.4)$$

$$P_{BS} = -Se^{-qT}N(-d_1) + Xe^{-rT}N(-d_2) \quad (6.5)$$

With:

$$\begin{aligned}
 S &= \textit{UnderlyingPrice} \\
 X &= \textit{Strike} \\
 T &= \text{Time to } \textit{Maturity} \\
 r &= \textit{CurrentShortRate} \\
 q &= \textit{DivYield} \\
 \sigma &= \textit{Vol}
 \end{aligned}$$

- For **Asian options**: Asian options are priced using the above formulas (6.4) but with the following modified parameters:

$$\begin{aligned}
 q &= \frac{1}{2} \left(\textit{CurrentShortRate} + \textit{DivYield} + \frac{\textit{Vol}^2}{6} \right) \\
 \sigma &= \textit{Vol} / \sqrt{3}
 \end{aligned}$$

- For **American options**: Cox-Rubinstein model (cf. Hull 2005).
- For **Binary options**: For binary options the price of a call and a put using the same variables as defined for European options read:

$$C_{bin} = e^{-rT} N(d_2) \quad (6.6)$$

$$P_{bin} = e^{-rT} N(-d_2) \quad (6.7)$$

- For **Barriers options**: The following variables are used for pricing barrier options:

$$\begin{aligned}
 S &= \textit{UnderlyingPrice} \\
 X &= \textit{Strike} \\
 H &= \textit{Barrier} \\
 h &= \textit{BarrierHit} \text{ (boolean "yes" or "no")} \\
 R &= \textit{Rebate} \\
 T &= \text{Time to } \textit{Maturity} \\
 r &= \textit{CurrentShortRate} \\
 q &= \textit{DivYield} \\
 \sigma &= \textit{Vol}
 \end{aligned}$$

To simplify notation, we will use the following abbreviations:

$$\begin{aligned}
m &= \frac{r - q - \sigma^2/2}{\sigma^2} \\
\lambda &= \frac{r - q + \sigma^2/2}{\sigma^2} \\
\lambda_2 &= \sqrt{m^2 + 2(r - q)/\sigma^2} \\
y &= \frac{\log\left(\frac{H^2}{SX}\right)}{\sigma\sqrt{T}} + \lambda\sigma\sqrt{T} \\
x_1 &= \frac{\ln(S/H)}{\sigma\sqrt{T}} + \lambda\sigma\sqrt{T} \\
y_1 &= \frac{\ln(H/S)}{\sigma\sqrt{T}} + \lambda\sigma\sqrt{T} \\
x_2 &= \frac{\ln(S/H)}{\sigma\sqrt{T}} + (1 + m)\sigma\sqrt{T} \\
y_2 &= \frac{\ln(H/S)}{\sigma\sqrt{T}} + (1 + m)\sigma\sqrt{T} \\
z &= \frac{\ln(H/S)}{\sigma\sqrt{T}} + \lambda_2\sigma\sqrt{T}
\end{aligned}$$

Moreover, the following expressions are used for pricing the value of the rebate for knock-in (DownInRebate and UpInRebate) and knock-out (DownOutRebate and UpOutRebate) options:

$$\text{UpInRebate} = Re^{-rT} \left[N(-x_2 + \sigma\sqrt{T}) - (H/S)^{2m} N(-y_2 + \sigma\sqrt{T}) \right] \quad (6.8)$$

$$\text{DownInRebate} = Re^{-rT} \left[N(x_2 - \sigma\sqrt{T}) - (H/S)^{2m} N(y_2 - \sigma\sqrt{T}) \right] \quad (6.9)$$

$$\text{UpOutRebate} = R \left[(H/S)^{m+\lambda_2} N(-z) + (H/S)^{m-\lambda_2} N(-z + 2\lambda_2\sigma\sqrt{T}) \right] \quad (6.10)$$

$$\text{DownOutRebate} = R \left[(H/S)^{m+\lambda_2} N(z) + (H/S)^{m-\lambda_2} N(z - 2\lambda_2\sigma\sqrt{T}) \right] \quad (6.11)$$

The following formulas are used to price barrier options:

Down-knock-in call option:

If $S \leq H$ or $h = \text{true}$:

$$C = C_{BS}$$

else if $H \leq X$:

$$C = Se^{-qT} (H/S)^{2\lambda} N(y) - Xe^{-rT} (H/S)^{2\lambda-2} N(y - \sigma\sqrt{T}) + \text{DownInRebate}$$

else if $H > X$:

$$\begin{aligned}
C &= C_{BS} - (SN(x_1)e^{-qT} - Xe^{-rT} N(x_1 - \sigma\sqrt{T}) - Se^{-qT} (H/S)^{2\lambda} N(y_1) \\
&\quad + Xe^{-rT} (H/S)^{2\lambda-2} N(y_1 - \sigma\sqrt{T})) + \text{DownInRebate}
\end{aligned}$$

Down-knock-out call option:If $S \leq H$ or $h = \text{true}$:

$$P = Re^{-rT}$$

else if $H \leq X$:

$$C = C_{BS} - (Se^{-qT} (H/S)^{2\lambda} N(y) - Xe^{-rT} (H/S)^{2\lambda-2} N(y - \sigma\sqrt{\sigma})) + \text{DownOutRebate}$$

else if $H > X$:

$$\begin{aligned} C &= SN(x_1)e^{-qT} - Xe^{-rT} N(x_1 - \sigma\sqrt{T}) - Se^{-qT} (H/S)^{2\lambda} N(y_1) \\ &+ Xe^{-rT} (H/S)^{2\lambda-2} N(y_1 - \sigma\sqrt{T}) + \text{DownOutRebate} \end{aligned}$$

Up-knock-out call option:If $S \geq H$ or $h = \text{true}$:

$$C = Re^{-rT}$$

else if $H \leq X$

$$C = \text{UpOutRebate}$$

else if $H > X$:

$$\begin{aligned} C &= C_{BS} - (SN(x)e^{-qT} - Xe^{-rT} N(x_1 - \sigma\sqrt{T}) - Se^{-qT} (H/S)^{2\lambda} (N(-y) - N(-y_1))) \\ &+ Xe^{-rT} (H/S)^{2\lambda-2} (N(-y + \sigma\sqrt{T}) - N(-y_1 + \sigma\sqrt{T})) + \text{UpOutRebate} \end{aligned}$$

Up-knock-in call option:If $S \geq H$ or $h = \text{true}$:

$$C = C_{BS}$$

else if $H \leq X$:

$$C = C_{BS} + \text{UpInRebate}$$

else if $H > X$:

$$\begin{aligned} C &= SN(x_1)e^{-qT} - Xe^{-rT} N(x - \sigma\sqrt{T}) - Se^{-qT} (H/S)^{2\lambda} (N(-y) - N(-y_1)) \\ &+ Xe^{-rT} (H/S)^{2\lambda-2} (N(-y + \sigma\sqrt{T}) - N(-y_1 + \sigma\sqrt{T})) + \text{UpInRebate} \end{aligned}$$

Down-knock-in put option:If $S \leq H$ or $h = \text{true}$:

$$P = P_{BS}$$

else if $H > X$

$$P = P_{BS} + \text{DownInRebate}$$

else if $H \leq X$

$$\begin{aligned} P &= -SN(-x_1)e^{-qT} + Xe^{-rT} N(-x_1 + \sigma\sqrt{T}) + Se^{-qT} (H/S)^{2\lambda} (N(y) - N(y_1)) \\ &- Xe^{-rT} (H/S)^{2\lambda-2} (N(y - \sigma\sqrt{T}) - N(y_1 - \sigma\sqrt{T})) + \text{DownInRebate} \end{aligned}$$

Down-knock-out put option:If $S \leq H$ or $h = true$:

$$P = e^{-rT} R$$

else if $H > X$

$$P = \text{DownOutRebate}$$

else if $H \leq X$:

$$\begin{aligned} P &= P_{BS} - (-SN(-x_1)e^{-qT} + Xe^{-rT}N(-x_1 + \sigma\sqrt{T}) + Se^{-qT}(H/S)^{2\lambda}(N(y) - N(y_1)) \\ &\quad - Xe^{-rT}(H/S)^{2\lambda-2}(N(y - \sigma\sqrt{T}) - N(y_1 - \sigma\sqrt{T}))) + \text{DownOutRebate} \end{aligned}$$

Up-knock-out put option:If $S \geq H$ or $h = true$:

$$P = e^{-rT} R$$

else if $H \geq X$

$$P = P_{BS} - (-Se^{-qT}(H/S)^{2\lambda}N(-y) + Xe^{-rT}(H/S)^{2\lambda-2}N(-y + \sigma\sqrt{T})) + \text{UpOutRebate}$$

else if $H < X$:

$$\begin{aligned} P &= -SN(-x_1)e^{-qT} + Xe^{-rT}N(-x_1 + \sigma\sqrt{T}) + Se^{-qT}(H/S)^{2\lambda}N(-y_1) \\ &\quad - Xe^{-rT}(H/S)^{2\lambda-2}N(-y_1 + \sigma\sqrt{T}) + \text{UpOutRebate} \end{aligned}$$

Up-knock-in put option:If $S \geq H$ or $h = true$:

$$P = P_{BS}$$

else if $H \geq X$:

$$P = -Se^{-qT}(H/S)^{2\lambda}N(-y) + Xe^{-rT}(H/S)^{2\lambda-2}N(-y + \sigma\sqrt{T}) + \text{UpInRebate}$$

else if $H < X$

$$\begin{aligned} P &= P_{BS} - (-SN(-x_1)e^{-qT} + Xe^{-rT}N(-x_1 + \sigma\sqrt{T}) + Se^{-qT}(H/S)^{2\lambda}N(-y_1) \\ &\quad - Xe^{-rT}(H/S)^{2\lambda-2}N(-y_1 + \sigma\sqrt{T})) + \text{UpInRebate} \end{aligned}$$

6.3 Literature

Beyer, R.C.M., Chen, R., Li, C., Misch, F., Ozturk, E.O., and Ratnovski, L. (2024) "Monetary Policy Pass-Through to Interest Rates: Stylized Facts from 30 European Countries" IMF Working Paper, No. WP/24/9. January 2024. Available at: imf.org.

Drechsler, I., Savov, A., and Schnabl, P. (2017) "The Deposits Channel of Monetary Policy" The Quarterly Journal of Economics, Vol. 132, Issue 4, pp. 1819–1876. DOI: 10.1093/qje/qjx019

Hull, John: Options, Futures And Other Derivatives, Prentice Hall, 2005.

Hull, John; White, Alain: Forward rate volatilities, swap rate volatilities and the implementation of the Libor market model, Joseph L. Rotman School of Management, University of Toronto, August, 1999.

Neumark, D. and Sharpe, S.A. (1992) "Market Structure and the Nature of Price Rigidity: Evidence from the Market for Consumer Deposits" The Quarterly Journal of Economics, Vol. 107, Issue 2, pp. 657–680.nDOI: 10.2307/2118485

Polo, A. (2021) "Imperfect Pass-Through to Deposit Rates and Monetary Policy Transmission" Bank of England Staff Working Paper, No. 933. Published 30 July 2021. SSRN: 3900542 Available at: bankofengland.co.uk

*When you finish reading this book, tie a stone to it and cast it into the midst of the Euphrates.
Jeremiah 51, 63*

