LDI Deep Dive Series
Part 1: Impact of interest rates on investment returns

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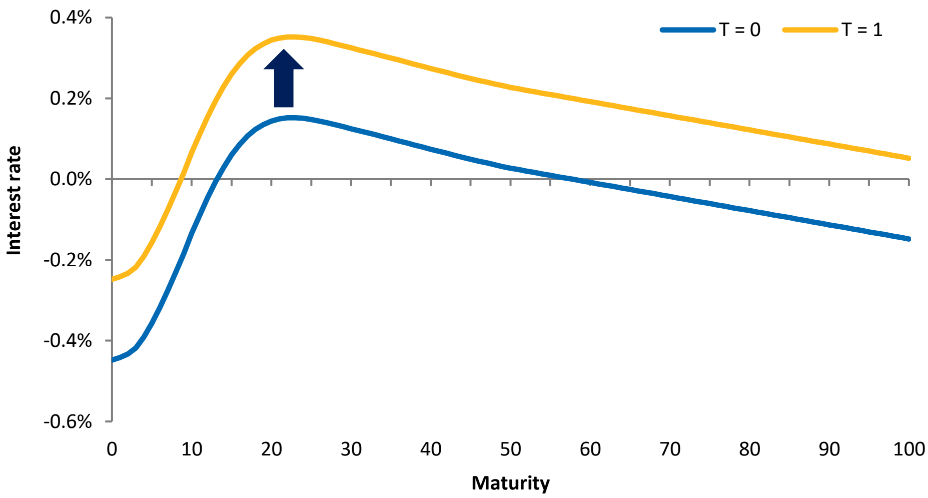
Investors with future liabilities are normally exposed to interest rate risk. A fall in interest rates will increase the value placed on future liabilities. By adopting a liability-driven investment (LDI) strategy, much of this interest rate risk can be mitigated. In this LDI Deep Dive Series, we will investigate the most important considerations for developing successful LDI strategies. In future articles we will consider curve shape and basis risk. We will then consider how a good LDI strategy should protect against the various interest rate risk components, and how much focus should be given to each. This first article considers protecting against changes in the general level of interest rates.

The first – and normally by far the most significant – component of interest rate risk is caused by changes in the general level of interest rates. This can be investigated by considering parallel shocks of the interest rate curve – the effect of the entire interest rate curve moving up or down to the same degree. A hypothetical parallel interest rate shock is illustrated in Figure 1. The extent of the exposure to parallel interest rate movements of a set of future liabilities can be measured by the "duration" or the "PV01". Duration can be defined as the weighted average maturity of the cash flows forming the liabilities and represents relative interest rate risk (if the interest rate curve changes by x%, the value of the liabilities will change by approximately x% multiplied by the duration). PV01 on the other hand represents the (absolute) nominal change in the value of the liabilities when the interest rate curve changes by 1 basis point (0.01%).

Figure 1: Parallel shock to the term structure



Source: Bloomberg and Aegon Asset Management. Term structure of the euro swap rate per 31 August 2020 (blue) and after a hypothetical 0.2% increase.

The interest rate risk of the liabilities can be hedged by investing in assets with a similar interest rate sensitivity to the liabilities. An increase in the value of liabilities due to a decrease in interest rates will then be (partly) compensated by an increase in the value of the assets.

When the assets have the same PV01 as the liabilities, the sensitivity of the liabilities to parallel interest rate curve movements can be thought of as fully hedged against parallel interest rate shocks. From a risk perspective it is optimal to hedge a high proportion of this interest rate risk. However, from an expected return perspective it can be desirable to leave some interest rate risk unhedged.

Interest rate characteristics and their influence on expected returns

Expected returns can be impacted by interest rate changes in various ways, of which we will discuss four important examples below.

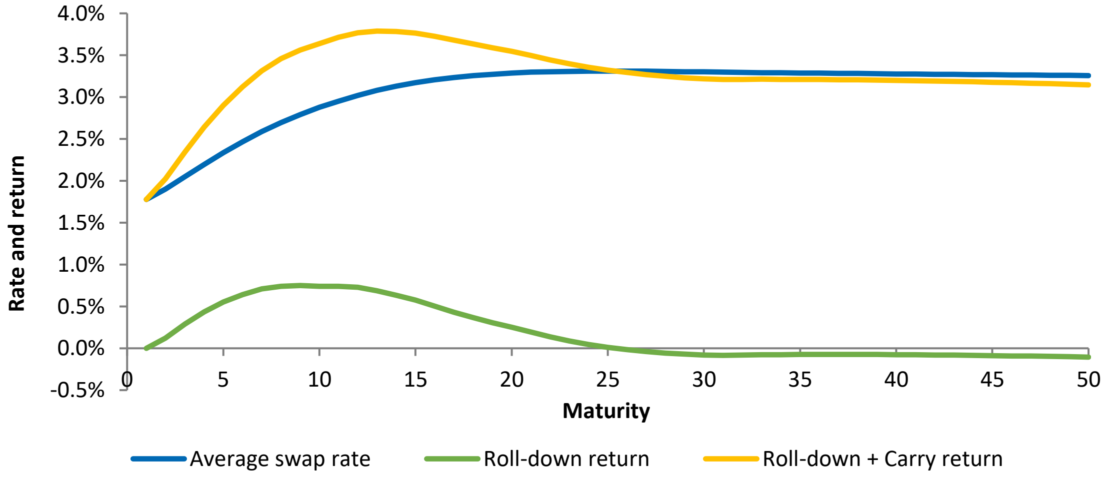
1. Term premium

During most periods the interest rate at longer maturities is higher than the interest rate at shorter maturities. An upward sloping term structure can be the result of market expectations and/or a risk premium. If the market view is that interest rates will rise, then forward rates will be higher than spot rates and this translates into an upward sloping term structure.[1]

An upward sloping interest rate curve can also represent a term premium. Because their duration is higher, bonds with longer maturities have greater interest rate sensitivity, greater price volatility, and more credit uncertainty (even for highly-rated government bonds). Investors therefore will generally require a higher expected annual return relative to bonds with shorter maturities and lower volatility. In other words, investors require a higher interest rate for investing at a longer maturity because they face greater uncertainty of how much their bond will be worth at a given point in time. Figure 2 shows the average term structure of euro interest rate swaps between 2000 and 2020. During this period the 10-year interest rate was, on average, 1.2% higher than the 1-year interest rate.

Figure 2 also shows the so-called "roll-down return" on the basis of this average interest rate curve. The roll-down return represents the return that a bond with a single cashflow at that maturity would experience over a one year period, in addition to the swap rate at that maturity. This is on the assumption that the interest rate curve does not change over that year. The roll-down return is dependent on the maturity, the level of interest rates at that maturity, and, importantly, the steepness of the curve at that maturity. We can see from Figure 2 that it can vary considerably by maturity and can also be negative where the slope of the curve is negative.

Figure 2: Average interest rate, expected roll-down return and expected roll-down & carry return



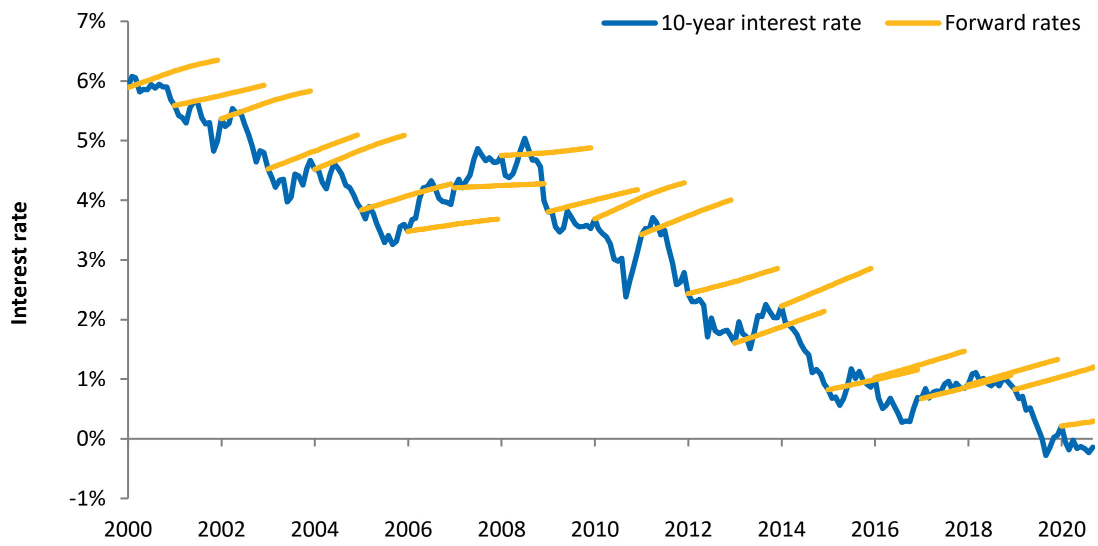
Source: Aegon Asset Management, Bloomberg. Average interest rate and expected roll-down return from January 2000 until August 2020.

[1] Otherwise there will be a risk-free arbitrage opportunity which should disappear quickly in an efficient market.

The return on a bond in a given year can therefore be represented by three elements: 1) any coupons which become payable in that year; 2) all the future bond cash flows coming one year closer to maturity; and 3) those cash flows being valued with a lower discount rate than the year before (if we assume an upward sloping term structure). The second effect can be termed the "carry" on the bond and the last effect, the roll-down return.[2]

Although it is difficult to separate the term premium from market expectations, Figure 3 shows that, between 2000 and 2020, forward rates consistently implied interest rates would rise. In reality, interest rates actually decreased quite strongly over this period (from 6% to 0%). While it is possible that market expectations were consistently wrong, the most logical conclusion is that a term premium is built into the interest rate term structure. This means that, in most market conditions, an upward sloping yield curve will be sustained. In certain circumstances, such as in anticipation of a recession, market expectations may overwhelm this effect and we will observe an inverted yield curve (shorter rates higher than longer rates) but such conditions are generally short-lived.

Figure 3: Interest rate versus forward predictions



Source: Aegon Asset Management, Bloomberg. The 10-year swap rate and implied expectations of forward rates from January 2000 until August 2020. Forward rates interpolated using 10-year forward rates in 1 and 2 years.

If there is indeed a consistent term premium, than hedging (more) interest rate risk also increases expected return. The return on swaps and long-term fixed income categories can be significantly higher than the returns on cash, assuming the term premium persists. Investors can add value by positioning along the term structure in such a way they can optimally benefit from carry and roll-down returns whilst maintaining the same overall level of hedging. This will however also introduce curve risk for the investor, as we shall explore in a later article in this series.

2. Interest rate forecast

A second potential source of return from interest rate exposure is through predicted changes in interest rates. Because the value of fixed income assets increases (or decreases) as the interest rate declines (or rises), investors can potentially add value by increasing their interest rate exposure when they expect interest rates to decrease and decreasing interest rate exposure when they expect them to increase. Although this can potentially add value, it is very difficult to reliably and accurately predict interest rate changes and the timing of those changes. This can be illustrated by the fact that while markets have priced in expected rises in interest rates during the last two decades –

[2] Other definitions are often used. Here we follow the definitions adopted by Kikugawa et al., 2017, "Bond Fund Performance and a Smart Beta Strategy in Japan", Securities Analyst Journal, 55(2), 69-80.

as suggested by the forward rates in Figure 3 – rates have actually kept declining over that period. Whether investors should attempt to generate return from this source is dependent on their investment beliefs regarding interest rates, their conviction in those beliefs, the expertise that they believe they and their investment managers have, and also how much risk they can afford to take.

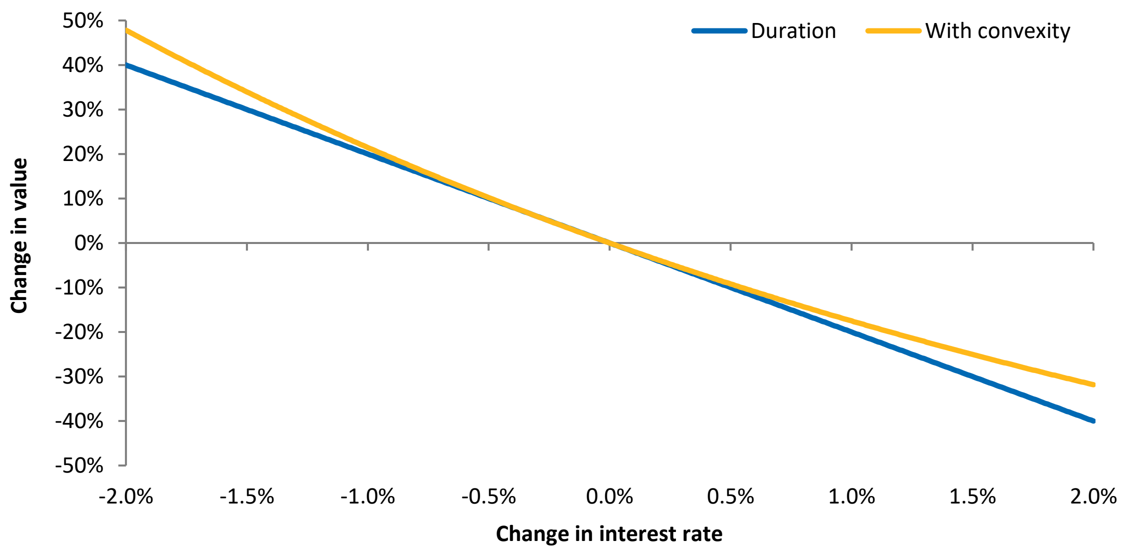
3. Convexity

Convexity presents a third impact on return from interest rate exposure. Convexity describes the characteristic of fixed income assets to increase more in value from a drop in interest rates than to decrease in value from an equal rise in interest rates.

The impact of convexity is illustrated in Figure 4. In this figure the blue line represents the (symmetric) valuation impact of interest rate changes as calculated with duration, while the yellow line includes the effect of convexity on the valuation. Looking only at the duration, the impact of a 2% increase or decrease in the interest rate is -40% and +40% respectively for a (zero-coupon) bond with maturity of 20 years; with an average of 0% for these two scenarios. However, when we also take convexity into account, the impact of a 2% increase or decrease in the interest rate improves from -40% to -31.8% and from +40% to +47.8%. The average of these two scenarios is 8.0%, significantly higher than the 0% when convexity is not included.

The impact of convexity is greater, the greater the duration of the fixed income asset. This means that investors may have a preference for longer dated swaps and fixed income assets in their hedging portfolio as a way of offering greater protection against large interest rate shocks. However, this may come into conflict with other considerations, such as maximizing the benefit of the roll-down return discussed previously, and also the generally lower liquidity for longer maturity instruments. It should also be noted that the value of the liabilities are also subject to the effect of convexity, so convexity in itself will not lead to outperformance relative to the liabilities. By positioning along the curve, as we will discuss in a later article, it can however be used to an investor's benefit.

Figure 4: Impact of convexity



Source: Aegon Asset Management. Impact of interest rate changes with and without convexity.

4. Oscillation benefits

Finally, the interest rate hedge can add expected return by profiting from oscillation (a repetitive variation) in interest rates. Historical analysis shows that interest rates tend to oscillate around a certain level or trend. By making use of a dynamic, asymmetric interest rate hedging strategy, one can benefit from such an oscillating behavior by having a lower interest rate hedge for interest rate increases than for similar decreases. The impact of such a dynamic interest rate hedging strategy is illustrated in Figure 5.

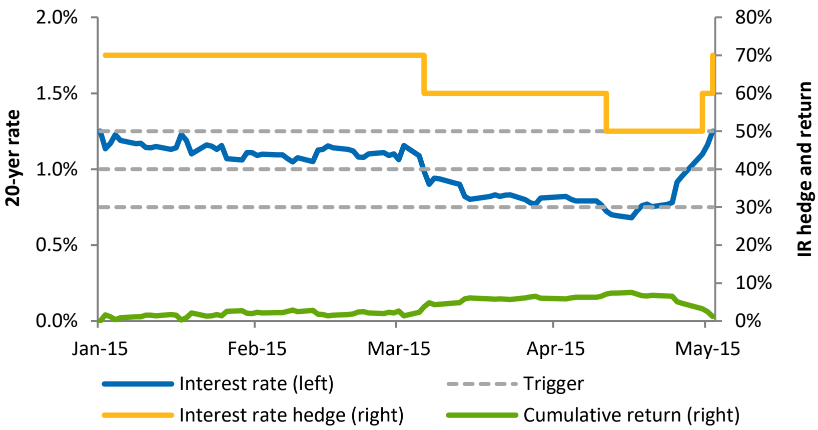
In the period from January 2015 to May 2015, the 20-year interest rate decreased from 1.25% to 0.68% before increasing to 1.25% again. We have analyzed a dynamic hedging strategy as shown in Table 1. At the two triggers (1.00% and 0.75%) the interest rate hedge was reduced twice, to 60% and 50% respectively, before being increased back to 60% and 70% at triggers of 1.00% and 1.25%. The result is that the average hedge during the decrease in interest rate was higher (65%) than the hedge during the rise back to 1.25% (55%). This resulted in a net increase in the funding ratio of approximately 1% over the period January to May 2015.

In recent historic periods, we have seen such oscillations frequently, periods in which a dynamic interest rate hedge would have generated excess returns. We will discuss the benefits of a dynamic interest rate hedge in more detail in a forthcoming article in this series.

Table 1: Example dynamic interest rate hedge

Trigger	Hedge level
1.50%	80%
1.25%	70%
1.00%	60%
0.75%	50%
0.50%	40%

Figure 5: Workings of dynamic hedge



Source: Aegon Asset Management, Bloomberg. Example workings dynamic hedge from January 2015 until May 2015.

Considerations for setting an interest rate hedging level

These four different potential ways in which interest rate changes can influence returns imply that different hedging strategies can influence expected returns. While the term premium and convexity motivate higher hedging levels, interest rate forecasts and oscillation benefits can also suggest lower hedging levels. This is summarized in Table 2 below.

Table 2: Directions for excess return

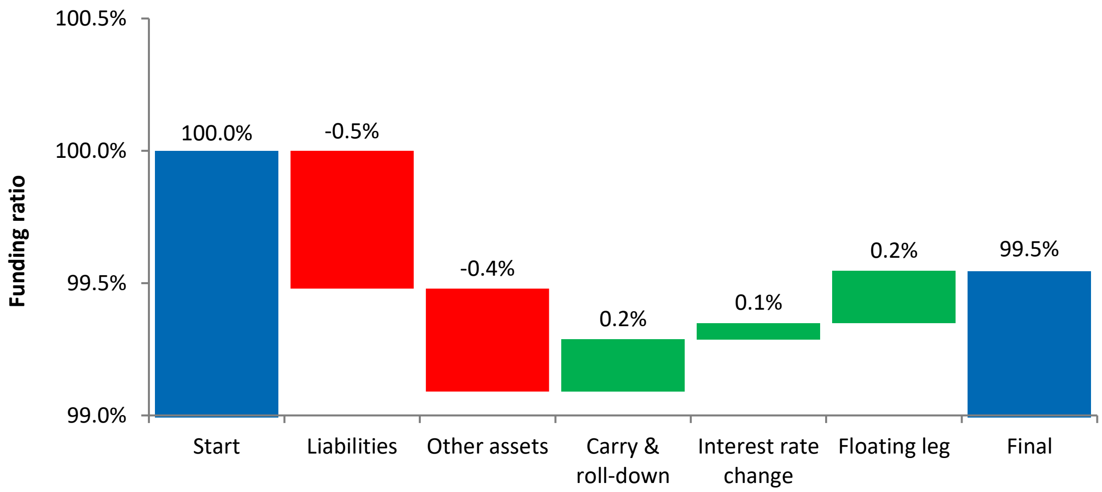
Potential source of excess return	Direction of interest rate hedge for higher return
Term premium	Higher
Interest rate forecast	Dependent on forecast
Convexity	Higher
Oscillation benefits	Dependent on interest rate movements

In order to analyze the combined impact of different interest rate hedging levels from the four sources of return on expected return, we simulate 2,000 different interest rate paths (scenarios). These scenarios cover a wide diversity of interest rate paths, but with an average interest rate change of zero. Furthermore, we assume that the cash flows of the interest rate hedge match those of the liabilities (in this case study for an average Dutch pension plan) perfectly.

Using these interest rate scenarios we can analyze the impact of different levels of interest rate hedging. In this article we only consider fixed interest rate hedge levels. In a later article we will also consider dynamic strategies. Because we now only consider fixed interest rate hedges, the impact on return is only dependent on the term premium (carry & roll-down) and changes in the interest rate. As the average interest rate of the scenarios is equal to the starting interest rate, returns from changes in the interest rate are due to convexity.

Figure 6 shows the average annual funding ratio development with an interest rate hedge of 50%, using a starting funding ratio of 100%. On average, the value of the liabilities increases as a result of the term premium and convexity, which, in turn, reduces the funding ratio. The impact of physical assets (like government bonds) for which the risk-free rate is used[3], is also negative given the average negative short-term rate. Due to the presence of a term premium, the carry & roll-down is positive for the interest rate hedge despite the negative short-term rate, while the average funding ratio increases as well, due to interest rate changes (convexity). Finally, the impact of the floating leg of the receiver swaps overlay is positive as this on average meant paying a negative variable rate (therefore receiving a positive fixed rate). Over a 20-year period the funding ratio on average deteriorates by 9.1% as a result of not fully hedging the interest rate risk. In addition, the funding ratio risk (tracking error[4]) increases when the interest rate is not fully hedged. We find on average a tracking error of 7.7%, which translates to a 32% probability that the funding ratio in a given year will change by more than +7.7% or –7.7% than the average of -0.5% due to parallel interest rate movements alone. The average maximum drawdown[5] in the 20-year period due to parallel interest rate risk is -27.7% for a 50% hedge.

Figure 6: Average funding ratio impact (50% fixed IR hedge)



Source: Aegon Asset Management. Illustration of annual impact on funding ratio given a fixed 50% interest rate hedge. Average of 2,000 scenarios. Assuming (on average) fixed interest rates.

[3] As we wish to focus on parallel interest rate risk, we intentionally do not take other risk factors, such as equity risk and credit risk, into account. Without risk exposure, physical assets with no interest rate sensitivity, would yield (approximately) the risk-free rate.
[4] Annual divergence between assets and liabilities, equal to the standard deviation of the funding ratio.
[5] Maximum observed loss from a peak to a trough of the funding ratio.

Without the expectation that the interest rate will (on average) increase, having a fixed interest rate hedge below 100% will be suboptimal both in terms of expected return and risk. Over the analyzed horizon of 20 years the interest rate should increase by 1.0% in order to break even on a below 100% interest rate hedge, or about 5 basis points per year. Without this expectation investors adopting a liability driven investment strategy would do better to fully hedge their interest rate risk, or use a dynamic interest rate hedge (as we will discuss in the second article).

The results for other fixed levels of interest rate hedges are given in Table 3. This shows that the impact on return and risk from the interest rate hedge is almost linear to unhedged interest rate exposures. In other words, decreasing the hedge from 50% to 0% (i.e. doubling the interest rate exposure versus the liabilities) almost doubles both the expected (negative) return and risk from the hedge.

Table 3: Impact of fixed interest rate hedging levels

Funding ratio impact	**Hedge 0%**	**Hedge 25%**	**Hedge 50%**	**Hedge 75%**	**Hedge 100%**	**Hedge 125%**	**Hedge 150%**
Liabilities	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
Other assets (risk-free rate)	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
Carry & roll-down	0.0%	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%
Interest rate change	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%
Floating leg	0.0%	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%
Total	**-0.9%**	**-0.7%**	**-0.5%**	**-0.2%**	**0.0%**	**0.2%**	**0.5%**
Tracking error	16.0%	11.7%	7.7%	3.8%	0.0%	3.8%	8.1%
Maximum drawdown	-49.0%	-39.0%	-27.7%	-14.9%	0.0%	-12.6%	-24.0%

Source: Aegon Asset Management. Annual funding ratio impact and risk for different fixed interest rate hedge levels. Average over 2,000 scenarios. Assuming (on average) fixed interest rates.

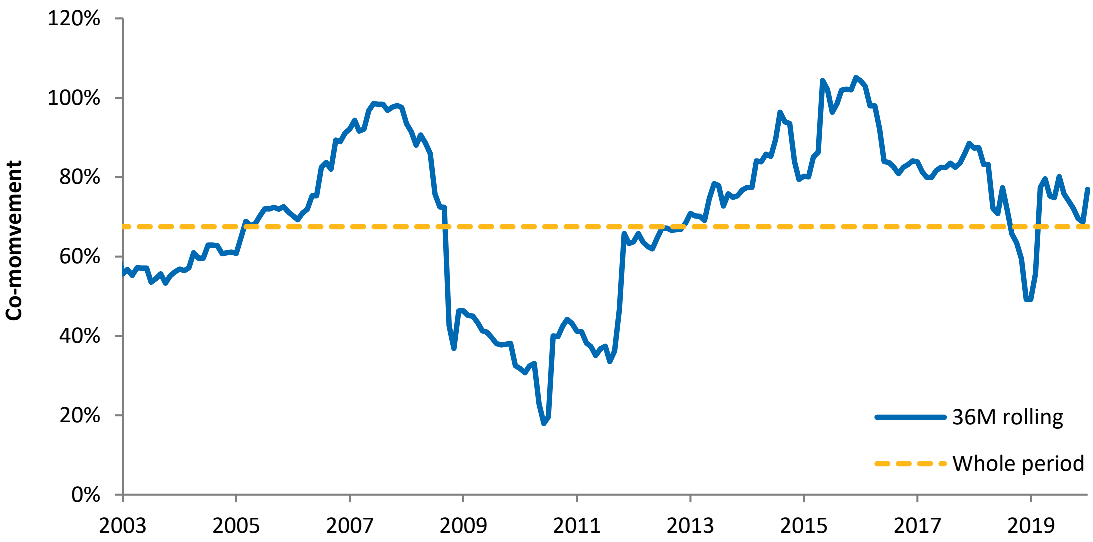
Interest rate hedging from a real perspective

So far we have analyzed interest rate risk from a nominal perspective. However, for investors who look at real liabilities (taking into account expected inflation) a different level of (nominal) interest rate hedge may be desired. Nominal interest rates consist of two components: the real interest rate and expected inflation. If nominal interest rates increase because inflation expectations increase, these two factors will counteract one another for an inflation sensitive liability – the future value of liabilities will increase due to the inflation correction but the discount factor will also increase as a result of the higher interest rate. Even though the nominal interest rate has changed, the real value of the liabilities may not and therefore from a real perspective the interest rate hedge should not provide a return as well.

The minimum-volatility hedge from a real perspective using a nominal interest rate depends on the co-movement between the nominal and real interest rate, which is dependent on the volatility of expected inflation. Figure 7 shows the co-movement using German inflation-linked bonds as a proxy for real liabilities. As the figure shows, the co-movement (36-months rolling) differs strongly over time. Over the whole period the co-movement is 67.5%, while it is significantly higher (77.9%) in the last decade due to lower and less volatile expected inflation rates. For an investor with real liabilities, a nominal interest rate hedge of approximately 70% would therefore minimize risk.

Of course, such an investor could use inflation-linked bonds or inflation swaps to better match real liabilities and be less dependent on the relation between nominal and real interest rates. However, for investors that have both nominal and real targets, it is valuable to know that hedging 100% will reduce the volatility of the nominal targets but may increase the volatility of the real targets.

Figure 7: Co-movement of nominal and real investments



Source: Bloomberg, Aegon Asset Management. Slope regression coefficient of German inflation linked bonds and (6-month Euribor) interest rate swaps, controlling for duration.

Conclusion

In this first article of the series on liability-driven investments, we have looked at the risk of changes in the general level of interest rates. Changes in interest rate levels can have a large impact on the valuation of liabilities. By adding interest rate sensitivity to the assets – interest rate hedging - this risk can be (partially) mitigated. Besides reducing volatility, an interest rate hedge also affects expected returns.

We gave four examples of ways in which interest rate hedging strategy can lead to potential excess returns: the term premium, interest rate forecasts, convexity and oscillation of the interest rate. While it has proven difficult to accurately predict interest rate movements, the other three sources can have a significant effect on expected returns. When the interest rate is expected to remain the same – increases and decreases in interest rates are viewed as equally likely – liabilities will on average increase in value due to the term premium and convexity. A fixed hedge lower than 100% will, in that case, mean the hedging strategy lags the value of the liabilities, therefore deteriorating the funding position, while also maintaining higher funding position volatility. However, it is important to note that a 100% nominal interest rate hedge reduces the risk in nominal terms but may increase the risk in real terms.

A more dynamic interest rate hedge strategy – benefiting from oscillations in the interest rate – can potentially increase expected returns. We will explore dynamic interest rate hedging further in the second article of this series.

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