

# Rules for Currency Hedging

Version: 1.0

# Bloomberg

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## ➤ UNHEDGED RETURNS

An investor who buys foreign currency on one day and sells it back the following day will realize a return,  $X_t$ , equal to the FX appreciation of the foreign currency relative to the local currency:

$$X_t = \frac{S_t - S_{t-1}}{S_{t-1}} \quad (1)$$

where  $S_{t-1}$  and  $S_t$  are the spot exchange rates on the two days.

The realized return for an investor buying a bond in a foreign currency and selling it the following day will include the impact of the FX appreciation as well as the return of the bond in its local currency. We refer to the currency of the bond's denomination as the local currency and the chosen currency of the portfolio or index as the base currency. The return of this security in the base currency on day  $t$  can be computed using the following inputs.  $M_t$  and  $M_{t-1}$  are the market values in local currency at the close of day  $t$  and  $t-1$  respectively.  $S_t$  and  $S_{t-1}$  are the spot exchange rates on these two days quoted as the units of base currency in one unit of the local currency. Therefore, the base currency market values of this security are  $M_t S_t$  and  $M_{t-1} S_{t-1}$  respectively. The linear return in base currency can be computed as follows:

$$\begin{aligned} R_t^{Base} &= \frac{M_t S_t}{M_{t-1} S_{t-1}} - 1 \\ &= \left( \frac{M_t}{M_{t-1}} \right) \cdot \left( \frac{S_t}{S_{t-1}} \right) - 1 \end{aligned} \quad (2)$$

This return calculation assumes that there are no cash payments such as coupons or principal payments during the return period. In the case that a cash payment does occur, the cash value is added to the ending market value to get the correct return.

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Rewriting Equation ( 2 ) above using the ratio of market values as the local return and the ratio of spot exchange rates as the FX appreciation, the return of this security in the base currency on day  $t$  can be computed as follows:

$$\begin{aligned} R_t^{Base} &= (1 + R_t^{Local}) \cdot (1 + X_t) - 1 \\ &= R_t^{Local} + X_t \cdot (1 + R_t^{Local}) \\ &= Local\ Return + Currency\ Return \end{aligned} \quad (3)$$

where  $R_t^{Local}$  is the local return and is computed as the ratio of local market values minus one, and  $X_t$  is computed using Equation ( 1 ) above. The base currency return is the sum of the Local Return, the FX appreciation, and the interaction term of the two. For simplicity, the interaction term is combined with the FX appreciation and defined as the Currency Return. The currency returns on bonds denominated in the same currency are therefore slightly different because the currency return contains the interaction term. The currency return can also be thought of as the difference between the base currency return of the bond and its local return.

To calculate the return for longer time periods, local returns are calculated daily and then compounded over the full time period.

## Example: Unhedged Returns

In this example we have an index with USD as the base currency which contains a single bond denominated in AUD (the local currency). The values needed to calculate the unhedged returns as well as the calculations themselves are provided in Table 1 below. The bond's local return in the month of August 2015 is 0.91%. The beginning and ending spot AUD/USD FX rates are 0.7346 and 0.7089 respectively which, using Equation ( 1 ), equates to an FX depreciation of  $(0.7089 - 0.7346)/0.7346 = -3.50\%$ . During the month of August, AUD fell 3.50% against USD. The Currency Return (which includes the interaction term) can be calculated from Equation ( 3 ) as:  $(-0.035) \cdot (1 + 0.0091) = -3.53\%$  (which is very close to the pure FX depreciation of -3.50%, the difference of -0.03% comes from the interaction term). The total return of the bond in USD (base currency) can be computed as the sum of the Local Return and the Currency Return:  $(0.91\%) + (-3.53\%) = -2.62\%$ . The relative weakening of AUD this month dominated the positive local return (in AUD) such that the unhedged

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total return in USD was -2.62% even though the total return in AUD was positive 0.91%. The table below provides the details behind these calculations.

Unhedged Index Return Calculations for LBANK 4.25% 08/07/25 (ISIN AU3CB0223097) in August 2015		
Local Return	0.91%	
AUD/USD Spot 7/31/15	0.7346	
AUD/USD Spot 8/31/15	0.7089	
FX Appreciation	-3.50%	= (0.7089 - 0.7346)/0.7346
Currency Return	-3.53%	= (-0.035)*(1+0.0091)
Total Return (Unhedged) in USD	-2.62%	= 0.0091+-0.0353

Table 1. Example Unhedged Index Calculations

## ➤ HEDGED RETURNS

In the example above, investing in the AUD security with USD as the base currency resulted in the performance of the bond going from positive (0.91% in AUD) to negative (-2.62% in USD) because of the dramatic depreciation of AUD relative to USD. Exchange rate movements can be a significant risk. To mitigate this risk, an investor may choose to hedge out currency risk in the portfolio. In this case, the investor would likely use a currency hedged index as the benchmark.

Assume there is an index with a certain base currency which contains only one bond that is denominated in a currency different than the base currency. If the bond's market value at the beginning of the month is  $M_0$ , to hedge this exposure, one would need to sell that amount of the local currency one month forward. The ideal size of the hedge would be the end of month market value of the bond which is unknown when the hedge is established. Bloomberg indices estimate this value using the beginning of month market value and the beginning bond yield; this assumes that the market value of the bond is expected to increase at the rate of its yield. We denote  $H$  as the hedge ratio using the following formula:  $H = P \cdot \left(1 + \frac{y}{2}\right)^{1/6}$  where  $P$  is the percentage hedging required and the total value of the hedge is  $M_0 \cdot H$ . For the rest of this document we assume that the index will be 100% hedged ( $P = 100\%$ ) and remove it from the equation. If the initial forward rate is  $F_0$ , the one month return of the bond and currency hedge would be the following:

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$$\begin{aligned}
 R_{1m}^{Base} &= \frac{M_T \cdot S_T + M_0 \cdot H \cdot (F_0 - S_T)}{M_0 \cdot S_0} - 1 & (4) \\
 &= \left( \frac{M_T}{M_0} \right) \cdot \left( \frac{S_T}{S_0} \right) - 1 + H \cdot \frac{(F_0 - S_T)}{S_0} \\
 &= (1 + R_t^{Local}) \cdot (1 + X_t) - 1 + H \cdot \frac{(F_0 - F_t)}{S_0} \\
 &= R_{1m}^{Local} + X_{1m} \cdot (1 + R_{1m}^{Local}) + H \cdot \frac{(F_0 - S_T)}{S_0} \\
 &= Local\ Return + Currency\ Return + Forward\ Return
 \end{aligned}$$

The last term  $\frac{(F_0 - S_T)}{S_0}$  is often referred to as the Forward Return. The Forward Return and the Currency Return cancel out each other to a large extent and therefore the hedged return is close to the local return. To see that, we can re-arrange the hedged return:

$$\begin{aligned}
 R_{1m}^{Base} &= R_{1m}^{Local} + X_{1m} \cdot (1 + R_{1m}^{Local}) + H \cdot \frac{(F_0 - S_T)}{S_0} & (5) \\
 &= R_{1m}^{Local} + X_{1m} \cdot (1 + R_{1m}^{Local}) + H \cdot \frac{(F_0 - S_0)}{S_0} - H \cdot \frac{(S_T - S_0)}{S_0} \\
 &= R_{1m}^{Local} + \left( H \cdot \frac{(F_0 - S_0)}{S_0} + X_{1m} \cdot (1 + R_{1m}^{Local} - H) \right)
 \end{aligned}$$

The base currency hedged return is still expressed as the sum of a local currency return and a hedged currency, which is basically the sum of the unhedged currency return and the forward return (the first line in the above equation). After rearranging, the second two terms have different meanings. The first, known at the beginning of the month,  $H \cdot \frac{(F_0 - S_0)}{S_0}$ , is often referred to as the FX carry return. It is proportional to the short term interest rate differential of the two currencies and it can be either positive or negative depending on relative short term rates. The second term,  $X_{1m} \cdot (1 + R_{1m}^{Local} - H)$  measures the contribution of the residual currency exposure due to the imperfection of the estimate or the under-hedge in the case of an intentional partial hedge.

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## Example: Hedged Returns

Continuing the example above, Table 2 below provides the values needed to calculate the hedged returns as well as the calculations themselves. The yield of this bond at the beginning of the month is 3.46%, resulting in a hedge ratio of  $(1 + 0.0346/2)^{(1/6)} = 1.00286$ . The Currency Return calculated using Equation ( 3 ) is -3.53%. The 1 month forward AUD/USD rate is 0.7320 and represents the forward exchange rate on the start date of the month (7/31/15) settling exactly on the last day of the month (8/31/15). The Forward Return calculated using Equation ( 4 ) is  $(1.00286) * (0.7320 - 0.7089) / 0.7346 = 3.15\%$ . The total hedged return is the sum of the Local Return, Currency Return, and Forward Return and is  $(0.0091) + (-0.0353) + (0.0315) = 0.53\%$ . The table below provides details on the calculations.

<b>Hedged Index Return Calculations for LBANK 4.25% 8/7/25 (ISIN AU3CB0223097) in August 2015</b>		
<i>Local Return</i>	0.91%	
Yield 7/31/15	3.46%	
Hedge Ratio	1.00286	$= (1 + 0.0346/2)^{(1/6)}$
AUD/USD Spot 7/31/15	0.7346	
AUD/USD Spot 8/31/15	0.7089	
FX Appreciation	-3.50%	$= (0.7089 - 0.7346) / 0.7346$
<i>Currency Return</i>	-3.53%	$= (-0.035) * (1 + 0.0091)$
AUD/USD 1M Forward 7/31 to 8/31	0.7320	
<i>Forward Return</i>	3.15%	$= 1.00286 * (0.7320 - 0.7089) / 0.7346$
<i>Total Return (Hedged) in USD</i>	0.53%	$= 0.0091 + -0.0353 + 0.0315$

Table 2. Example Hedged Index Calculations

Note that with the hedge the return in USD is significantly closer to the local currency return of 0.91% thereby reducing the effect of the AUD depreciation. Hedges are designed to be implementable by investors at the beginning of the month and therefore are not perfect; the bond will still have currency exposure in the index after hedging which accounts for the difference between these returns.

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The hedged return calculation above is for a full month; however, the return of a hedged portfolio must also be calculated intra-month for month-to-date returns. To compute the MTD hedged return for any day  $t$ , we need to mark-to-market the forward contract on day  $t$ . As the forward rate at the beginning of the month (settling at the end of the month) is denoted as  $F_0$ , we denote the forward rate on day  $t$  settling at the end of the month by  $F_t$ . The MTD hedged return is given by the following:

$$\begin{aligned} R_{MTD}^{Base} &= \frac{M_t S_t + M_0 H * (F_0 - F_t)}{M_0 S_0} - 1 \\ &= R_t^{Local} + X_t (1 + R_t^{Local}) + H \frac{(F_0 - F_t)}{S_0} \\ &= Local\ Return + Currency\ Return + Forward\ Return \end{aligned} \tag{6}$$

It is easy to see that the monthly return is a special case for this more generic MTD hedged return; at month end,  $F_T$  with a maturity on day  $T$  would be the spot exchange rate,  $S_T$ .

## Example: Hedged Returns Calculated Intra-Month

This exercise, for the same bond as above, uses the generalized formula in Equation ( 6 ) to calculate the hedged return for any date, in this case as of 8/14/15. During this time period the bond local return is given as -0.12%. The hedge ratio has been set at the beginning of the month and does not change. The spot AUD/USD exchange rate on 8/14/15 is 0.7374 and the Currency Return calculated using Equation ( 3 ) is 0.38%. The 1 month forward AUD/USD rate from the beginning of the month is 0.7320 and the forward from 8/14 to 8/31 is 0.7370. The Forward Return calculated using Equation ( 6 ) is  $(1.00286) * (0.7320 - 0.7370) / 0.7346 = -0.68\%$ . The Total Unhedged Return is the sum of the Local Return and Currency Return:  $(-0.0012) + (-0.0038) = -0.0050$ . The Total Hedged Return, adding in the Forward Return, is:  $(-0.0012) + (0.0038) + (-0.0068) = -0.0042$ . The table below provides details on the calculations.



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Hedged Index Return Calculations for LBANK 4.25% 8/7/25 (ISIN AU3CB0223097) for part of August 2015		
Local Return	-0.12%	
Yield 7/31/15	3.46	
Hedge Ratio	1.00286	$= (1 + 0.0346/2)^{(1/6)}$
AUD/USD Spot 7/31/15	0.7346	
AUD/USD Spot 8/14/15	0.7374	
FX Appreciation	0.38%	$= (0.7374 - 0.7346)/0.7346$
Currency Return	0.38%	$= (0.0038) * (1 - 0.0012)$
AUD/USD 1M Forward 7/31 to 8/31	0.7320	
AUD/USD 1M Forward 8/14 to 8/31	0.7370	
Forward Return	-0.68%	$= 1.00286 * (0.7320 - 0.7370)/0.7346$
Total Return (Unhedged) in USD	0.26%	$= -0.0012 + 0.0038$
Total Return (Hedged) in USD	-0.42%	$= -0.0012 + 0.0038 + -0.0068$

Table 3. Example Hedged Index Intra-Month Calculations

At this point during the month the local return of the bond is negative and AUD has appreciated against USD. In this case, the unhedged return in USD becomes positive (due to the AUD currency appreciation) and applying the hedge brings it closer in line with the local return which is negative.

In addition to calculating the return of the bond on any date, the market value of the bond (and therefore the index) can also be calculated on any date. Assume that the bond has market value of  $M_0$  (in local currency) at the beginning of the month. The total market value has two components, the market value of the bond converted into base currency, and the mark-to-market value of the hedge. On any day  $t$ , the market value of the bond in base currency is  $M_t \cdot S_t$ .

To hedge this exposure, the local currency is sold at the beginning of the month in the amount of the hedge,  $M_0 \cdot \left(1 + \frac{y}{2}\right)^{1/6}$ , with 1 month forward settlement. Assuming the forward rate settling at the end of the month is  $F_0$ , the mark to market of the hedge is  $M_0 \cdot \left(1 + \frac{y}{2}\right)^{1/6} \cdot (F_0 - F_t)$ .

$$M_t^{Base} = M_t \cdot S_t + M_0 \cdot \left(1 + \frac{y}{2}\right)^{1/6} \cdot (F_0 - F_t) \quad (7)$$

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