Cross-Currency Swap Calculator

Exercise Collection

English

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Notes on Working Through the Exercises

This exercise collection is designed as accompanying practice material for the Cross-Currency Swap Calculator V23. The exercises are divided into three difficulty levels:

- **Level 1 (Fundamentals):** Simple valuations and calculations
- **Level 2 (Advanced):** Sensitivities and risk analysis
- **Level 3 (Expert):** Complete VaR calculation and portfolio analysis

Recommended approach:

1. Read the exercise carefully
2. Enter the relevant parameters in the calculator
3. Carry out the calculations
4. Compare results with the model solutions
5. If there are discrepancies: check inputs and formulae

Important: All calculations should be followed through both in the calculator and by hand in order to deepen theoretical understanding.

1 Level 1: Fundamentals of Swap Valuation

1.1 Discount Factors and Cash Flows

Exercise 1.1

Calculate the discount factors for the following zero rates using continuous compounding:

Tenor	Zero Rate
1Y	2.50%
2Y	2.75%
3Y	3.00%

Formula: $DF(t) = e^{-r(t)\cdot t}$

Solution:

$$DF(1) = e^{-0.025\times 1} = e^{-0.025} = 0.975310$$
$$DF(2) = e^{-0.0275\times 2} = e^{-0.055} = 0.946485$$
$$DF(3) = e^{-0.030\times 3} = e^{-0.090} = 0.913931$$

Calculator input:

- Market Data tab: enter EUR rates for 1Y, 2Y, 3Y
- Swap Details: choose 3 annual payments
- Calculate Swap Valuation
- In the cash flow table: check the Discount Factor column

Exercise 1.2

The EUR leg of a cross-currency swap has the following specification:

- Notional: €5 000 000
- Fixed rate: 3.00% p.a.
- Payments: annual, 3 years
- Discount factors from Exercise 1.1

Calculate:

a) The three annual coupon payments

b) The present value of each cash flow

c) The total value of the EUR leg (excluding final principal)

Solution:

a) Coupon payments:
Annual coupon $= 0.03 \times 5{,}000{,}000 = 150{,}000$ EUR
All three payments: €150 000 each

b) Present values:

$$PV_1 = 150{,}000 \times 0.975310 = 146{,}297 \text{ EUR}$$
$$PV_2 = 150{,}000 \times 0.946485 = 141{,}973 \text{ EUR}$$
$$PV_3 = 150{,}000 \times 0.913931 = 137{,}090 \text{ EUR}$$

c) Total value:

$$PV_{\text{coupons}} = 146{,}297 + 141{,}973 + 137{,}090 = 425{,}360 \text{ EUR}$$

Calculator verification: Sum of the PV column in the EUR cash flow table (excluding the final row with the principal).

Exercise 1.3

Extend Exercise 1.2 by adding the final principal at the end of year 3.
Calculate:

a) The present value of the principal

b) The total PV of the EUR leg (coupons + principal)

Solution:

a) PV of the principal:

$$PV_{\text{principal}} = 5{,}000{,}000 \times 0.913931 = 4{,}569{,}655 \text{ EUR}$$

b) Total PV:

$$PV_{EUR} = 425{,}360 + 4{,}569{,}655 = 4{,}995{,}015 \text{ EUR}$$

Interpretation: The EUR leg is worth €4 985 less than the notional, due to the discounting effect over 3 years at 3% rates.

1.2 Complete Swap Valuation

Exercise 1.4

Value a cross-currency swap with the following parameters:
Swap specification:

- Notional EUR: €8 000 000
- Notional USD: $9 000 000
- Payment frequency: annual

- Number of payments: 3
- Pay leg: EUR
- Receive leg: USD
- FX rate: 1.125 (EUR/USD)

EUR yield curve:

- 1Y: 2.80%, 2Y: 2.90%, 3Y: 3.00%

USD yield curve:

- 1Y: 4.00%, 2Y: 4.10%, 3Y: 4.20%

Calculate the net present value of the swap.

Solution:

Step 1: EUR leg (pay)
Fixed rate = 3.00% (3Y rate)
Discount factors:

$$DF_{EUR}(1) = e^{-0.028\times 1} = 0.972376$$
$$DF_{EUR}(2) = e^{-0.029\times 2} = 0.943739$$
$$DF_{EUR}(3) = e^{-0.030\times 3} = 0.913931$$

Coupon = $0.03 \times 8{,}000{,}000 = 240{,}000$ EUR

$$\begin{aligned} PV_{EUR} &= 240{,}000 \times (0.972376 + 0.943739 + 0.913931) \\ &\quad + 8{,}000{,}000 \times 0.913931 \\ &= 680{,}171 + 7{,}311{,}448 = 7{,}991{,}619 \text{ EUR} \end{aligned}$$

Step 2: USD leg (receive)
Fixed rate = 4.20% (3Y rate)
Discount factors:

$$DF_{USD}(1) = e^{-0.040\times 1} = 0.960789$$
$$DF_{USD}(2) = e^{-0.041\times 2} = 0.921312$$
$$DF_{USD}(3) = e^{-0.042\times 3} = 0.881878$$

Coupon = $0.042 \times 9{,}000{,}000 = 378{,}000$ USD

$$\begin{aligned} PV_{USD} &= 378{,}000 \times (0.960789 + 0.921312 + 0.881878) \\ &\quad + 9{,}000{,}000 \times 0.881878 \\ &= 1{,}044{,}303 + 7{,}936{,}902 = 8{,}981{,}205 \text{ USD} \end{aligned}$$

Step 3: Convert to EUR

$$PV_{USD}^{EUR} = 8{,}981{,}205 \times 1.125 = 10{,}103{,}856 \text{ EUR}$$

Step 4: Net present value

$$\text{Net PV} = 10{,}103{,}856 - 7{,}991{,}619 = 2{,}112{,}237 \text{ EUR}$$

Interpretation: The swap has a positive value of approx. €2.11m, since the received USD leg is worth more than the paid EUR leg.

2 Level 2: Sensitivities and Greeks

2.1 Numerical Sensitivities

Exercise 2.1

Consider a simple 2-year cross-currency swap:
Parameters:

- Notional EUR: €10 000 000
- Notional USD: $11 000 000
- Payment frequency: annual
- Pay EUR, receive USD
- FX rate: 1.10
- EUR rates: 1Y = 3.00%, 2Y = 3.20%
- USD rates: 1Y = 4.00%, 2Y = 4.20%

Calculate the sensitivity of the swap value to the EUR 1Y rate using the bump-and-reprice method (bump = 1bp).
Hint: First calculate the base PV, then the PV with the bumped 1Y rate.

Solution:

Step 1: Calculate base PV
Using the given rates (analogous to previous exercises):

$$\text{Net PV}_{\text{base}} = 1{,}423{,}789 \text{ EUR} \quad \text{(example value)}$$

Step 2: Bump the EUR 1Y rate
New EUR 1Y rate: $3.00\% + 0.01\% = 3.01\%$
Recalculate with the bumped rate:

$$\text{Net PV}_{\text{bumped}} = 1{,}422{,}825 \text{ EUR}$$

Step 3: Calculate sensitivity

$$\delta_{EUR,1Y} = \frac{\text{Net PV}_{\text{bumped}} - \text{Net PV}_{\text{base}}}{0.0001} = \frac{1{,}422{,}825 - 1{,}423{,}789}{0.0001} = -9{,}640$$

Interpretation:

- A 1bp increase in the EUR 1Y rate reduces the swap value by approx. €9 640

- Negative delta: higher EUR rates → lower swap value
- This is logical since we pay EUR (higher discounting = lower absolute value of the negative leg)

Calculator check:

1. Risk Metrics tab → Calculate Risk Metrics
2. EUR Curve Sensitivities → check the 1Y value

Exercise 2.2

For the same swap as in Exercise 2.1:
Calculate the FX sensitivity (delta FX). Bump the FX rate by 0.001 (from 1.10 to 1.101).
What does the sign of the FX sensitivity mean?

Solution:

Base PV: Net $\text{PV}_{\text{base}} = 1{,}423{,}789$ EUR
With FX = 1.101:
The USD leg becomes more expensive in EUR:

$$PV_{USD}^{EUR,\text{bumped}} = PV_{USD} \times 1.101$$

This increases the net PV:

$$\text{Net PV}_{\text{bumped}} = 1{,}433{,}789 \text{ EUR}$$

FX sensitivity:

$$\delta_{FX} = \frac{1{,}433{,}789 - 1{,}423{,}789}{0.001} = 10{,}000{,}000$$

Interpretation:

- Positive delta: higher FX rate → higher swap value
- For every 0.001 rise in the FX rate the swap value rises by €10m
- This corresponds approximately to the USD notional (we receive USD)
- We are long USD / short EUR → benefit from USD appreciation

2.2 Sensitivity Portfolio

Exercise 2.3

A portfolio consists of two cross-currency swaps:
Swap A:

- Notional: €5M / $5.5M
- 3 years, annual
- Pay EUR, receive USD

- $\delta_{EUR,2Y} = -4{,}500$

Swap B:

- Notional: €8M / $8.8M
- 3 years, annual
- Pay USD, receive EUR
- $\delta_{EUR,2Y} = +7{,}200$

Calculate:

a) The portfolio sensitivity to EUR 2Y

b) How the portfolio value changes for a +10bp rise in the EUR 2Y rate

Solution:

a) Portfolio sensitivity:
The deltas are additive:

$$\delta_{\text{Portfolio},EUR,2Y} = -4{,}500 + 7{,}200 = +2{,}700$$

b) Value change for +10bp:

$$\Delta PV = 2{,}700 \times 10 = +27{,}000 \text{ EUR}$$

Interpretation:

- Positive portfolio delta: the portfolio benefits from rising EUR 2Y rates
- Swap B dominates (larger notional, opposite direction)
- The positions partially hedge each other (Swap A short EUR 2Y, Swap B long EUR 2Y)

3 Level 3: Value at Risk and Portfolio Analysis

3.1 Covariance Matrix and Portfolio Volatility

Exercise 3.1

Consider a simple 2-year annual swap with 5 risk factors (2 EUR + 2 USD + 1 FX).
Sensitivity vector:

$$\boldsymbol{\delta} = \begin{pmatrix} -5000 \\ -4500 \\ +5500 \\ +5000 \\ +10000000 \end{pmatrix}$$

(EUR 1Y, EUR 2Y, USD 1Y, USD 2Y, FX)

Simplified covariance matrix (variances only, no correlations):

$$\boldsymbol{\Sigma} = \begin{pmatrix} 4 \times 10^{-8} & 0 & 0 & 0 & 0 \\ 0 & 4 \times 10^{-8} & 0 & 0 & 0 \\ 0 & 0 & 4 \times 10^{-8} & 0 & 0 \\ 0 & 0 & 0 & 4 \times 10^{-8} & 0 \\ 0 & 0 & 0 & 0 & 1 \times 10^{-6} \end{pmatrix}$$

Calculate the portfolio variance and portfolio volatility.
Hint: For a diagonal matrix: $\sigma_P^2 = \sum_i \delta_i^2 \Sigma_{ii}$

Solution:

Portfolio variance:
Since the covariance matrix is diagonal (no correlations):

$$\begin{aligned} \sigma_P^2 &= \delta_1^2\Sigma_{11} + \delta_2^2\Sigma_{22} + \delta_3^2\Sigma_{33} + \delta_4^2\Sigma_{44} + \delta_5^2\Sigma_{55} \\ &= (-5000)^2 \times 4 \times 10^{-8} + (-4500)^2 \times 4 \times 10^{-8} \\ &\quad + (5500)^2 \times 4 \times 10^{-8} + (5000)^2 \times 4 \times 10^{-8} \\ &\quad + (10{,}000{,}000)^2 \times 1 \times 10^{-6} \\ &= 1{,}000 + 810 + 1{,}210 + 1{,}000 + 100{,}000{,}000{,}000 \\ &\approx 100{,}000{,}004{,}020 \end{aligned}$$

Portfolio volatility:

$$\sigma_P = \sqrt{100{,}000{,}004{,}020} \approx 10{,}000 \text{ EUR}$$

Interpretation:

- FX risk completely dominates (10M delta $\times\sqrt{10^{-6}} = 10\,000$)
- Interest rate risks are negligibly small (combined only approx. 4 020)
- 1-day volatility: approx. €10 000

Exercise 3.2

Calculate the VaR for the portfolio in Exercise 3.1 at the 95% and 99% confidence levels.
Quantiles: $z_{0.95} = 1.645$, $z_{0.99} = 2.326$

Solution:

VaR 95%:

$$VaR_{95\%} = 1.645 \times 10{,}000 = 16{,}450 \text{ EUR}$$

VaR 99%:

$$VaR_{99\%} = 2.326 \times 10{,}000 = 23{,}260 \text{ EUR}$$

Interpretation:

- With 95% probability the 1-day loss will not exceed €16 450
- With 99% probability the 1-day loss will not exceed €23 260
- The expected shortfall (when exceeded) would be even higher
- Risk is almost entirely FX-driven

3.2 Full Covariance Matrix

Exercise 3.3

Extend Exercise 3.1 by adding correlations between the risk factors.
Assumptions:

- Correlation between EUR rates: $\rho = 0.9$
- Correlation between USD rates: $\rho = 0.9$
- Correlation EUR/USD rates: $\rho = 0.7$
- Correlation rates/FX: $\rho = 0.0$ (uncorrelated)

Calculate the covariance matrix from the correlation matrix and the standard deviations.
Hint: $\Sigma_{ij} = \rho_{ij} \times \sigma_i \times \sigma_j$
Standard deviations: $\sigma_{\text{rate}} = \sqrt{4 \times 10^{-8}} = 2 \times 10^{-4}$, $\sigma_{FX} = \sqrt{1 \times 10^{-6}} = 1 \times 10^{-3}$

Solution:

Standard deviations:

- $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = 2 \times 10^{-4}$
- $\sigma_5 = 1 \times 10^{-3}$

Covariance matrix (selected elements):
Diagonal (variances):

- $\Sigma_{11} = \Sigma_{22} = \Sigma_{33} = \Sigma_{44} = 4 \times 10^{-8}$
- $\Sigma_{55} = 1 \times 10^{-6}$

EUR–EUR correlations ($i, j \in \{1, 2\}$):

$$\Sigma_{12} = \Sigma_{21} = 0.9 \times 2 \times 10^{-4} \times 2 \times 10^{-4} = 3.6 \times 10^{-8}$$

USD–USD correlations ($i, j \in \{3, 4\}$):

$$\Sigma_{34} = \Sigma_{43} = 0.9 \times 2 \times 10^{-4} \times 2 \times 10^{-4} = 3.6 \times 10^{-8}$$

EUR–USD correlations:

$$\Sigma_{13} = \Sigma_{14} = \Sigma_{23} = \Sigma_{24} = 0.7 \times 2 \times 10^{-4} \times 2 \times 10^{-4} = 2.8 \times 10^{-8}$$

FX correlations (all zero):

$$\Sigma_{15} = \Sigma_{25} = \Sigma_{35} = \Sigma_{45} = 0$$

Full matrix:

$$\mathbf{\Sigma} = 10^{-8} \times \begin{pmatrix} 4.0 & 3.6 & 2.8 & 2.8 & 0 \\ 3.6 & 4.0 & 2.8 & 2.8 & 0 \\ 2.8 & 2.8 & 4.0 & 3.6 & 0 \\ 2.8 & 2.8 & 3.6 & 4.0 & 0 \\ 0 & 0 & 0 & 0 & 100 \end{pmatrix}$$

Exercise 3.4

Calculate the new portfolio variance for the portfolio in Exercise 3.3, now accounting for correlations.

Use: $\sigma_P^2 = \boldsymbol{\delta}^\top \boldsymbol{\Sigma} \boldsymbol{\delta}$

Solution:

Calculating the quadratic form:

$$\sigma_P^2 = \sum_{i=1}^{5} \sum_{j=1}^{5} \delta_i \Sigma_{ij} \delta_j$$

Main contributions:

- Diagonal (as in Ex. 3.1): $\approx 100{,}000{,}004{,}020$
- $\delta_1 \delta_2 \Sigma_{12}$: $2 \times (-5000) \times (-4500) \times 3.6 \times 10^{-8} = 1{,}620$
- $\delta_1 \delta_3 \Sigma_{13}$: $2 \times (-5000) \times 5500 \times 2.8 \times 10^{-8} = -1{,}540$
- $\delta_1 \delta_4 \Sigma_{14}$: $2 \times (-5000) \times 5000 \times 2.8 \times 10^{-8} = -1{,}400$
- (further terms similar)

Estimated total variance:

$$\sigma_P^2 \approx 100{,}000{,}005{,}000$$

Portfolio volatility:

$$\sigma_P = \sqrt{100{,}000{,}005{,}000} \approx 10{,}000.0003 \text{ EUR}$$

Interpretation:

- Correlations between rates have only minimal impact (approx. +1 000 on variance)
- FX risk continues to dominate (100 000 000 of 100 000 005)
- Diversification effects between rates are negligible
- The high correlation between EUR and USD rates (0.7) has little effect because the deltas are of opposite sign and partially offset each other

3.3 Synthetic Data and Backtesting

Exercise 3.5

You have generated synthetic data in the calculator for a 5-year annual swap (11 risk factors: 5 EUR + 5 USD + 1 FX).

Generation parameters:

- Number of days: 250

- Volatility: 0.01 (1% p.a.)
- Correlation: 0.3 (off-diagonal)

Resulting covariance matrix (excerpt):

- Variance EUR 1Y: 3.97×10^{-8}
- Variance FX: 1.02×10^{-6}

Your swap:

- Sensitivity EUR 1Y: −€8 500
- Sensitivity FX: +€12 000 000

Questions:

a) Does the observed variance match the input parameters?

b) Estimate the portfolio volatility (these two risk factors only, without correlation)

Solution:

a) Checking the variance:
Expected daily variance:

$$\sigma^2_{\text{day}} = \left(\frac{0.01}{\sqrt{252}}\right)^2 = \frac{10^{-4}}{252} \approx 3.97 \times 10^{-8}$$

This matches exactly the observed variance for EUR 1Y!
For FX (assumed higher volatility):

$$\sigma^2_{FX,\text{day}} = 1.02 \times 10^{-6} \quad \Rightarrow \quad \sigma_{FX,\text{annual}} = \sqrt{1.02 \times 10^{-6} \times 252} \approx 0.016 \ (1.6\%)$$

b) Portfolio volatility (without correlation):

$$\begin{aligned}\sigma^2_P &= \delta^2_{EUR,1Y} \times \Sigma_{EUR,1Y} + \delta^2_{FX} \times \Sigma_{FX} \\ &= (-8{,}500)^2 \times 3.97 \times 10^{-8} + (12{,}000{,}000)^2 \times 1.02 \times 10^{-6} \\ &= 2{,}869 + 146{,}880{,}000{,}000 \\ &\approx 146{,}880{,}003{,}000\end{aligned}$$

$$\sigma_P = \sqrt{146{,}880{,}003{,}000} \approx 12{,}120 \text{ EUR}$$

Interpretation:

- 1-day portfolio volatility: approx. €12 120
- FX risk dominates (12M delta!)
- Interest rate risk contributes only €2 869 to variance (0.002%)

4 Additional Exercises: Advanced Scenarios

Exercise 4.1 – Multi-Swap Portfolio

A trader has three cross-currency swaps in the portfolio:

Parameter	Swap 1	Swap 2	Swap 3
Notional EUR	€10M	€15M	€8M
Notional USD	$11M	$16.5M	$9M
Direction	Pay EUR	Pay USD	Pay EUR
Term	5Y	3Y	10Y
Frequency	Annual	Semi	Annual
$\delta_{EUR,2Y}$	−9,500	+12,000	−7,800
$\delta_{USD,2Y}$	+10,000	−13,500	+8,500
δ_{FX}	+11M	−16.5M	+9M

Calculate:

a) The net EUR 2Y sensitivity of the portfolio

b) The net USD 2Y sensitivity of the portfolio

c) The net FX sensitivity of the portfolio

d) Which risk factor dominates the portfolio risk?

Solution:

a) Net EUR 2Y sensitivity:

$$\delta_{\text{Portfolio},EUR,2Y} = -9{,}500 + 12{,}000 - 7{,}800 = -5{,}300$$

b) Net USD 2Y sensitivity:

$$\delta_{\text{Portfolio},USD,2Y} = 10{,}000 - 13{,}500 + 8{,}500 = +5{,}000$$

c) Net FX sensitivity:

$$\delta_{\text{Portfolio},FX} = 11{,}000{,}000 - 16{,}500{,}000 + 9{,}000{,}000 = +3{,}500{,}000$$

d) Dominant risk factor:
FX risk clearly dominates with a €3.5M delta, while the rate deltas are in the range of €5 000 (a factor of 700 smaller!).
Hedging recommendation:

- Short €3.5M FX forward to eliminate FX risk
- Optionally: EUR 2Y and USD 2Y rate futures for a perfect hedge

Exercise 4.2 – Stress Testing

For the portfolio in Exercise 4.1:
Calculate the value change under the following stress scenarios:

a) EUR 2Y rate rises by 50bp

b) USD 2Y rate falls by 30bp

c) FX rate rises by 5% (from 1.10 to 1.155)

d) Combined scenario: a) + b) + c) simultaneously

Which scenario is most damaging?

Solution:

a) EUR 2Y +50bp:

$$\Delta PV_a = -5{,}300 \times 50 = -265{,}000 \text{ EUR}$$

b) USD 2Y −30bp:

$$\Delta PV_b = 5{,}000 \times (-30) = -150{,}000 \text{ EUR}$$

c) FX +5% (= +0.055):

$$\Delta PV_c = 3{,}500{,}000 \times 0.055 = +192{,}500 \text{ EUR}$$

d) Combined scenario:

$$\Delta PV_{\text{total}} = -265{,}000 - 150{,}000 + 192{,}500 = -222{,}500 \text{ EUR}$$

Analysis:

- Most damaging single scenario: EUR 2Y +50bp (−€265k)
- The FX movement acts as a natural hedge in this scenario
- Combined loss: −€222.5k
- Worst case would be: EUR +50bp, USD −30bp, FX −5% → approx. −€607.5k

Exercise 4.3 – VaR Backtesting

You have a VaR model with the following parameters:

- Confidence level: 99%
- Time horizon: 1 day
- Calculated VaR: €50 000
- Backtest period: 250 trading days

During the backtest period the VaR was exceeded on 5 days.
Questions:

a) How many exceedances would be expected for a correct 99% VaR model?

b) Is the model too conservative, appropriate or too aggressive?

c) Calculate the exceedance rate

Solution:

a) Expected exceedances:
At the 99% confidence level we expect 1% exceedances:

$$E[\text{exceedances}] = 250 \times 0.01 = 2.5 \approx 2\text{–}3 \text{ days}$$

b) Model assessment:
Observed: 5 exceedances
Expected: 2–3 exceedances
The model is **too aggressive** (underestimates risk). The VaR should be higher.
c) Exceedance rate:

$$\text{Rate} = \frac{5}{250} = 0.02 = 2\%$$

This corresponds to an effective confidence level of only 98% rather than 99%.
Recommendation:

- Increase the VaR multiplier (e.g. from 2.326 to 2.5)
- Or: review the volatility estimate (possibly too low)
- Or: extend the model to include fat tails (Student-t instead of normal)

Appendix: Formulae and Constants

Key Formulae

Discount factor:

$$DF(t) = e^{-r(t) \cdot t}$$

Present value (coupon):

$$PV = \sum_{i=1}^{N} C_i \cdot DF(t_i)$$

Sensitivity (numerical):

$$\delta_i = \frac{PV(r_i + \varepsilon) - PV(r_i)}{\varepsilon}$$

Portfolio variance:

$$\sigma_P^2 = \boldsymbol{\delta}^\top \boldsymbol{\Sigma} \boldsymbol{\delta} = \sum_{i=1}^{n} \sum_{j=1}^{n} \delta_i \Sigma_{ij} \delta_j$$

Value at Risk:

$$VaR_\alpha = z_\alpha \cdot \sigma_P$$

Covariance from correlation:

$$\Sigma_{ij} = \rho_{ij} \cdot \sigma_i \cdot \sigma_j$$

Key Constants

Parameter	Value
z-score 90%	1.282
z-score 95%	1.645
z-score 99%	2.326
z-score 99.9%	3.090
Trading days per year	252
Calendar days per year	365
Basis point (bp)	0.0001

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