

Mat 2.108 Independent research projects in applied mathematics

Hedging contingent foreign currency exposures

HELSINKI UNIVERSITY OF TECHNOLOGY
Systems Analysis Laboratory
Jari Liede 45743M

Contents

1. Introduction	2
2. Foreign exchange hedging instruments	3
2.1. Quotation.....	3
2.2. Foreign exchange rates and volatilities.....	3
2.3. Foreign exchange forward.....	4
2.4. Foreign exchange option.....	6
2.5. Other foreign exchange hedging instruments.....	7
3. Risk of uncertain foreign exchange cash flows	8
4. Measuring foreign exchange risk	11
4.1. Cash-Flow-at-Risk.....	11
5. Development of the simulation model	12
5.1. Simulation of tender outcomes.....	14
5.2. Simulation of foreign exchange market outcomes.....	14
5.3. Simulation formulas.....	15
5.4. Other simulation settings.....	16
6. Analysis of results	17
6.1. Hedging with forwards.....	17
6.2. Hedging with options.....	18
6.3. Hedging with forwards and options.....	18
6.4. Implications for hedging decisions.....	19
7. Ideas for future research	20

1. Introduction

As a result of increased globalisation and international trade many companies face foreign exchange risk – i.e. risk due to fluctuations in currency exchange rates. Exchange rates are volatile and thus the risks faced by companies large. For example, the strengthening of EUR against USD from 0.83 in October 2000 to 1.36 in December 2004 – a change of 64% - damaged several exporting European companies severely.

It has become commonplace for companies to hedge against these risks using derivatives. For example, in surveys conducted by the Bank for International Settlements (BIS) the notional amount of outstanding over-the-counter derivatives had increased from \$94 trillion in June 2000 to \$170 trillion in June 2003 – an increase of more than 80% (Stulz 2004).

It has however been noted that companies hedge foreign exchange risk in certain cash flows much more commonly than in contingent cash flows. Contingent cash flows are cash flows that may or may not materialize, depending on a decision or action by a third party. In a recent Bank of America survey, more than 75% of firms were hedging foreign exchange cash flows but only 10% hedged contingent exposures (Bank of America 2004). This is significant because if the uncertain cash flow is realised and currency rates have moved unfavourably the losses are equally large as from a certain cash flow.

It is commonly assumed that the main reason not to hedge is the difficulty in finding a proper hedging strategy or hedging instrument for contingent cash flows. For example, using a currency forward or a currency loan to lock the receivable will end up, instead of hedging the risk position, increasing the risk position if the underlying uncertain cash flow is not realised.

In this paper a model for finding an optimal hedging strategy for uncertain currency flows is developed. The optimal strategy will depend on the probability of the contingent cash flow being realised. The model will allow using currency forwards, plain vanilla currency put options and their combinations as hedging instruments. Hedge ratio may be between 0 and 100%. The optimal hedging strategy is chosen based on Cash-Flow-at-Risk, using Monte Carlo simulation.

The applications of the model range from hedging the currency risk in currency-denominated tenders when bidding for contracts, to large-scale mergers and acquisitions transactions.

The outline of the paper is as follows. Section 2 introduces the hedging instruments and Section 3 includes a more thorough description of the underlying problem. Sections 4 and 5 include a description of the risk measure and the simulation model, respectively. The results are analysed in Section 6 and finally, Section 7 introduces ideas for further research.

2. Foreign exchange market and hedging instruments

2.1. Quotation

The standard way of expressing a foreign exchange rate is:

EUR/USD = 1.2000, where 1 euro equals 1.2000 US dollars.

The currency listed first is the base currency and the other currency is called the variable or price currency. In EUR/USD, EUR is the base currency and USD is the variable currency. The standard quotation of an FX rate tells how many units of variable currency one gets per one unit of base currency. In currency pairs where euro is one of the two currencies, euro is always the base currency. So even though EUR/USD = 1.2000 could also be put as USD/EUR = 0.8333, the first is the standard way of quoting this rate¹.

2.2. Foreign exchange rates and volatilities

EUR/USD is the most actively traded currency pair in the world. Table 1 lists the levels and volatilities of EUR/USD and other selected currency pairs on 31.12.2006. The volatilities are calculated from daily rate changes and then annualised. Although this is the common method, volatilities calculated in this way tend to underestimate the risk of currency rate changes. This is because currencies often trend i.e. move in the same direction for longer periods. In some cases these trends may last for several years. As can be noted in the table, even these –

¹ When GBP is quoted against any other currency than the euro, it is the base currency. Next in line come AUD and NZD.

perhaps too small – volatility figures are of reasonable magnitude and, thus, risks related to open currency positions are significant.

	Spot 31.12.2006	Volatility (5yr data)	Largest three month change (5yr data)
EURUSD	1,3172	8,8%	14,0%
EURGBP	0,6724	5,7%	8,4%
EURJPY	156,77	8,3%	10,1%
EURCHF	1,6084	3,1%	5,5%
EURSEK	9,0394	4,7%	3,6%

Table 1: Spot rates and volatilities of selected currency pairs

2.3. Foreign exchange forward

A forward contract is a contract to buy or sell an asset at a fixed date in the future (Luenberger 1998). An FX forward is an agreement to buy or sell an agreed amount of currency on a future date at a price agreed today. Forward contracts are zero-cost – no premium is paid when entering the contract. The FX forward rate is calculated based on the spot rate i.e. the current rate and the interest rates of the respective currencies using Equation 1 (Nordea 2004).

$$F = S * \frac{\left(1 + \left(r_v * \frac{d}{360}\right)\right)}{\left(1 + \left(r_b * \frac{d}{360}\right)\right)} \quad (1)$$

where

F is the forward rate

S is the current exchange rate (i.e. spot rate)

r_v is the variable currency interest rate

r_b is the base currency interest rate

d is the number of days to maturity

For example, if EUR/USD spot rate is 1.2100 and three-month interest rate is 4.5% for USD and 2.5% for EUR, the three-month forward rate is

$$F = 1.2100 * \left(\frac{1 + \left(4.5\% * \frac{90}{360} \right)}{1 + \left(2.5\% * \frac{90}{360} \right)} \right) = 1.2160$$

A company selling a currency benefits if the interest rate of this currency is lower than the interest rate of the bought currency and vice versa. In the example above, the forward rate is better than the spot rate for the buyer of USD and worse than the spot rate for the seller of USD.

At maturity, the forward contract has a positive market value if the agreed forward rate is better than the prevailing spot rate and a negative market value if the forward rate is worse than the spot rate. For example, an agreement to sell 1 million USD against EUR at 1.2160 has a positive value for the USD seller if the spot rate is 1.2200. The positive market value can be realised by buying USD at the spot market at 1.2200 and selling it using the forward at 1.2160 thus making a gain of

$$\frac{1000000 \text{ USD}}{1.2160 \text{ USD/EUR}} - \frac{1000000 \text{ USD}}{1.2200 \text{ USD/EUR}} = 2696 \text{ EUR}$$

The value – and the net cash flow – of a forward contract at maturity is therefore

for a forward to buy base currency and sell variable currency:

$$CF_{FWD_B} = n * \left(\frac{1}{F} - \frac{1}{S} \right) \quad (2)$$

for a forward to sell base currency and buy variable currency:

$$CF_{FWD_S} = n * \left(\frac{1}{S} - \frac{1}{F} \right) \quad (3)$$

where

n is the notional principal of the forward in variable currency

2.4. Foreign exchange option

An FX option gives its owner the right, but not the obligation, to buy or sell an agreed amount of currency on a future date at a price agreed today. An option that gives the right to purchase something is called a call option whereas an option that gives the right to sell is a put option (Luenberger 1998). With FX options, each option is always a put and a call at the same time. For example, for the currency pair EUR/USD, a EUR call is always a USD put and vice versa.

As the holder of an option has only rights and no obligations, options cost money. The price that the buyer of an option pays is called option premium. The premium depends on the option strike, volatility, interest rates and maturity. Price of an FX call option is often calculated using the Garman-Kohlhagen formula, which is an extension of the more widely known Black-Scholes formula (Garman et al. 1983).

$$p_C = Se^{-r_v t} N(d_1) - Xe^{-r_b t} N(d_2) \quad (4)$$

where

$$d_1 = \frac{\ln(S/X) + (r_b - r_v + \sigma^2/2) * t}{\sigma\sqrt{t}} \quad (5,6)$$
$$d_2 = \frac{\ln(S/X) + (r_b - r_v - \sigma^2/2) * t}{\sigma\sqrt{t}} = d_1 - \sigma\sqrt{t}$$

and where $N(x)$ denotes the standard cumulative normal probability distribution

and where

S is the current exchange rate (spot rate)

X is the option strike

r_v is the variable currency interest rate

r_b is the base currency interest rate

t is time to maturity in years

σ is the implied volatility for the underlying exchange rate

Equation 4 gives the premium in units of base currency per variable currency. To express the premium as a base currency amount, the result given by Equation 4 needs to be multiplied by the notional principal of the option in variable currency.

As the holder of an option has no obligations, the value of an option can never be negative. At maturity, the value and the cash flow of an option is either zero or similar with that of a forward with the same strike.

Therefore, using Equation 2, the cash flow of a call option at maturity is

$$CF_{OPT_C} = MAX(0, n * (\frac{1}{X} - \frac{1}{S})) \quad (7)$$

Using Equation 3, the cash flow of a put option at maturity is

$$CF_{OPT_P} = MAX(0, n * (\frac{1}{S} - \frac{1}{X})) \quad (8)$$

where

n is the notional principal of the option in variable currency

2.5. Other foreign exchange hedging instruments

The FX forward and the FX option presented above are often called plain vanilla hedges, as they are the simplest derivative hedging products available. A large variety of various exotic options – such as barrier and binary options – as well as other hedging instruments are also available (see e.g., Hull 1997). They are however not considered in this work as they are much more complex to implement in a hedging strategy and not equally widely used (see e.g., Bodnar et al. 1998).

3. Risk of uncertain foreign exchange cash flows

A project sale is one of the most common real-life examples where companies face risk of uncertain FX flows. Figure 1 describes the relevant steps of a project sale from FX risk point of view.

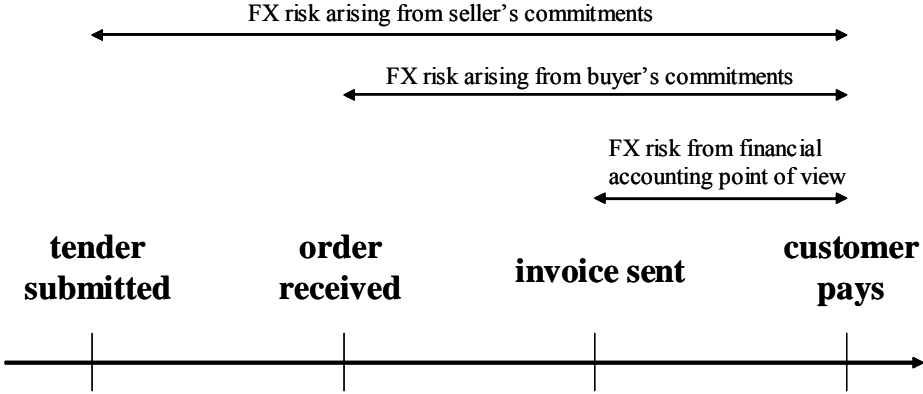


Figure 1: Timeline of selling a project

The FX gain or loss realised in accounting often results only from changes in FX rates between sending the invoice and the eventual payment. The receivable is commonly booked in the balance sheet when the invoice is sent. The company is however exposed to the FX risk for a much longer time. The FX risk is realised – at the latest – when the order is received. In the case of a project sale, the FX risk begins even earlier: when the tender is submitted. In a tender the company agrees to deliver the project at a fixed currency-denominated price. After pricing the tender, the company has usually no possibilities to increase the price even if billing currency depreciates.

Hedging is straightforward after the tender has been accepted – at that point the receivable is certain. On the other hand, it is obvious that no hedging is needed if the tender is not successful. The problems in hedging are related to the time-period between submitting the tender and its acceptance/non-acceptance as during that period the risk is open but the company does not know whether it becomes realised or not.

Problems related to hedging are reflected in the four-fields below.

1) Hedging 100% using a forward

	Tender accepted	Tender lost
Sales currency strengthens	Sales margin ok	Losses on the forward
Sales currency weakens	Sales margin ok	FX profits from forward

Table 1: Four outcomes when hedging 100% using a forward

If the sales currency weakens, the forward will produce a gain – this obviously is no problem. But on the other hand if the sales currency has strengthened, the forward will produce a loss. If, at the same time, the tender is accepted there is no problem as the underlying position – the currency denominated sales – has benefited from the currency move. The loss on the forward and the gain on the underlying position cancel each other out. However, if the tender is lost there is no underlying position and the loss on the forward will remain in the P&L of the company. The company has to close the forward by buying currency from the spot market – at a rate that is worse than the forward rate.

2) Hedging using a forward with a hedge ratio reflecting the probability of winning the tender – in the example 35% probability

	Tender accepted	Tender lost
Sales currency strengthens	Sales margin increased for 65% of currency move	Losses on the forward (35%)
Sales currency weakens	Sales margin worsened for 65% of currency move	FX profits from forward (35%)

Table 2: Four outcomes when hedging 35% using a forward

When probability of winning the tender is used as the hedge ratio, the hedge ratio will always be wrong no matter what happens. The underlying position will either be 100% or 0%. If the tender is accepted, company is under-hedged and if it is not accepted, company is over-hedged. Under-hedging will produce a loss if sales currency weakens and over-hedging if sales currency strengthens.

3) Hedging 100% using an option

	Tender accepted	Tender lost
Sales currency strengthens	Sales margin increased for 100% of currency move (-premium)	Premium lost
Sales currency weakens	Sales margin ok (- premium)	FX profits from option (-premium)

Table 3: Four outcomes when hedging 100% using an option

An option is a good hedging instrument in any of the scenarios. The worst-case outcome is that the premium is lost.

The only drawback with hedging options is having to pay the premium. Depending on the parameters – strike, volatility and maturity – the premium payment can be around 2-4% of the underlying notional amount. Thus, options are sometimes considered too expensive. On the other hand, if the option is correctly priced, the premium is only as big as the weighted average of the expected payoff².

² In 2006, the 1month implied volatility for EURUSD, calculated from option prices, was on average 7.6% whereas the realised volatility was approx. 7.0% for the same periods suggesting that EURUSD options were slightly overpriced in 2006.

4. Measuring foreign exchange risk

Academic literature focuses on volatility reduction as the primary objective for risk management (Stulz 1996). This is inconsistent with the aim of many corporate risk management programmes designed just to avoid lower-tail outcomes (Stulz 1996). Investors and corporate treasurers do not dislike upside volatility. In addition, the lower end tail outcomes can have, beyond losing money in the first place, also costly consequences for the company. These include, for example, not having enough resources to carry out the investment program (Stulz 2002).

Also Markowitz – the inventor of mean-variance framework – stated that semivariance, volatility below benchmark, seems more plausible than variance as a measure of risk (Markowitz 1959). Further evidence supporting downside risk measures can be found, for example in Froot et al. (1993), Froot et al. (1994) and Miller et al. (1996).

In this study, already the fact that options will be used as hedges – and thus the return distribution will be non-normal – disqualifies simple volatility as the measure of risk. The focus is here only on negative outcomes and Cash-Flow-at-Risk is chosen as the risk measure.

4.1. Cash Flow at Risk

Cash-Flow-at-Risk (CFaR) is the maximum shortfall of net cash generated, relative to a specified target, corresponding to some pre-defined probability level and risk horizon (RiskMetrics 1999). The probability level used – as defined by the left-hand tail of the cash flow distribution - is usually 5% or less. Figure 2 depicts CFaR at the 5% probability level.

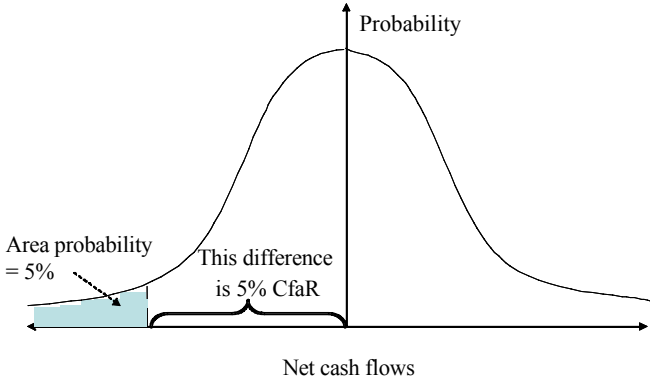


Figure 2. 5% CFaR

Cash-Flow-at-Risk was developed in response to increased interest from the business community in the methodology behind Value-at-Risk (VaR) – it is the cash-flow equivalent of VaR³. CFaR focuses on cashflows while VaR focuses on asset values and CFaR often looks out over a horizon of a quarter or a year while the horizon for VaR is typically measured in days or weeks (LaGattuta et al. 2001). CFaR is gaining popularity for much the same reasons as VaR has been recognised: it sums up company’s risk exposures into a single, manageable number that comes attached with probability and that can be directly compared to the firm’s risk tolerance (Andren et al. 2005).

CFaR is typically estimated through Monte Carlo simulation (Linsmeier et al. 2000). That is the approach used in this study also. Figure 3 shows an example of estimating CFaR from a histogram of net cash flows.

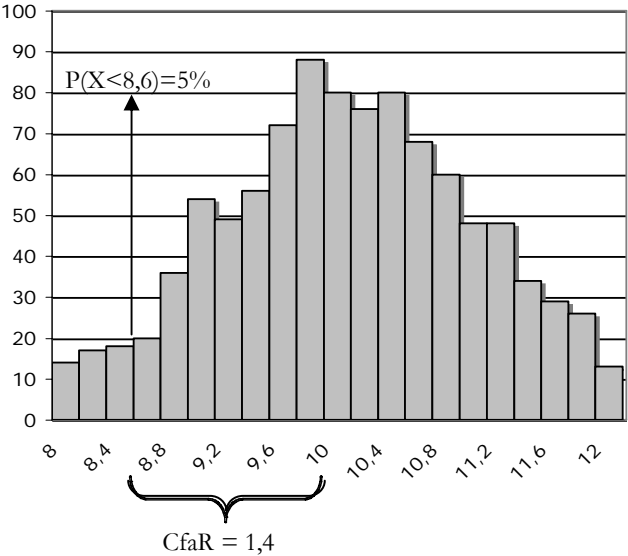


Figure 3. Estimating CFaR from a histogram of net cash flows

5. Development of the simulation model

The aim of the simulations is to solve the optimal hedging strategy for any probability of “winning the bid”. The extreme cases are intuitive – if there is very low probability, there

³ For a description of VaR, see for example Jorion 1997

should be no hedging at all and if the probability is very high, the company should hedge 100% using a forward. For all remaining probabilities we must simulate how the various hedging strategies would perform in terms of the chosen optimisation criteria.

The various probabilities of the tender being accepted used in the simulations are presented in Table 4.

Acceptance probabilities									
5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
55%	60%	65%	70%	75%	80%	85%	90%	95%	

Table 4: The probabilities of tender being accepted used in calculations

For each of the above-mentioned probabilities the result of the simulation is the following table (Table 5). Each grey cell will include the risk figure for that particular hedging strategy. The combined hedge ratio (forward + option) may not be more than 100%. The white cells are therefore not applicable. The cell with the lowest risk figure marks the optimal hedging strategy.

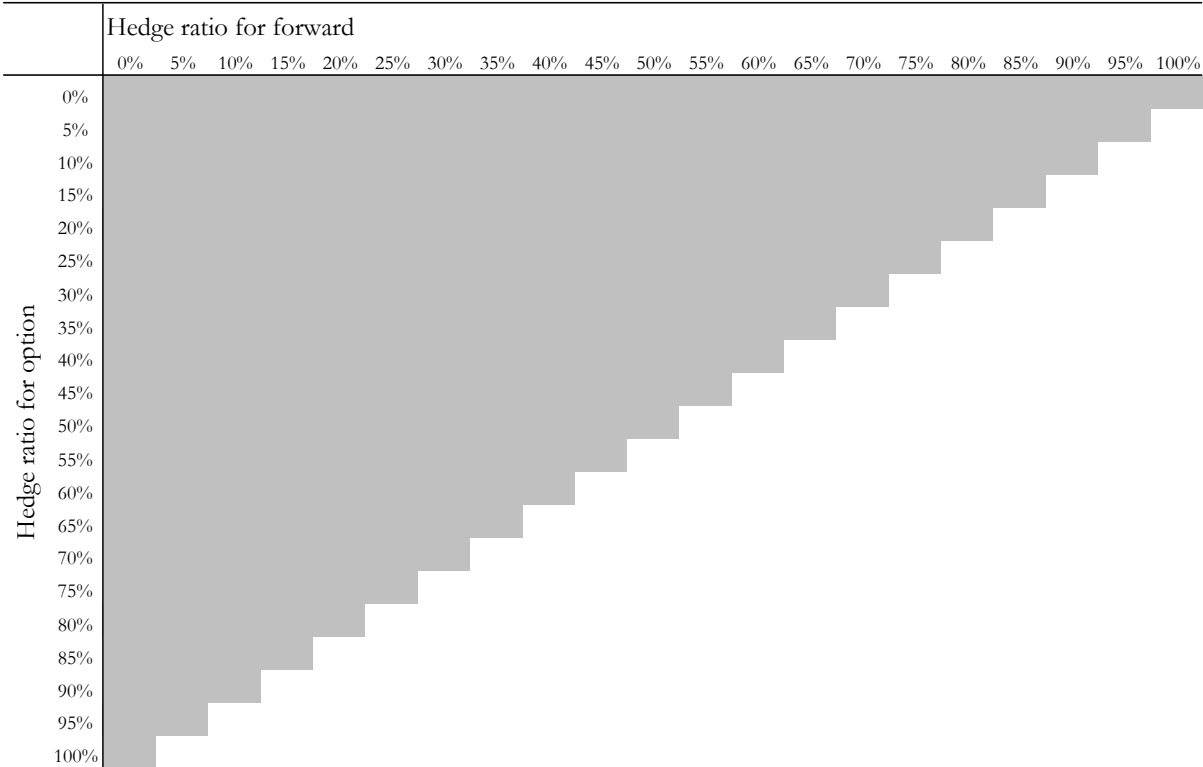


Table 5: Table presenting all 231 various hedging strategies simulated in the study

The risk measures are calculated through Monte Carlo simulation. The outcome distribution is a combination of two simulations: tender outcome and FX market outcome.

5.1. Simulation of tender outcomes

Tender outcome t is a binary variable $t \in \{0,1\}$.

$$t = \begin{cases} 0, & \text{if } X_1 > p_{acc} \\ 1, & \text{if } X_1 \leq p_{acc} \end{cases} \quad (11)$$

where

p_{acc} is the probability of tender being accepted

and where

X_1 is simulated using a uniform distribution $X_1 \sim \text{Unif}(0,1)$

5.2. Simulation of foreign exchange market outcomes

The standard approach for simulating the outcome of market movements would be to generate the price or return distributions for each security or asset. However, with instruments whose payoffs are non-linear – such as options – a better approach is to generate distributions for the underlying risk factors that affect an asset (Culp et al. 1998).

FX market outcome is thus generated by simulating future FX spot rate changes and then computing the profit and loss distributions for each hedging combination using these.

Changes in the spot rate are assumed to be normally distributed. As currencies are a zero-sum game the expected return is set at zero.⁴ The standard deviation is given by the market implied volatility.

⁴ There are almost as many forecasts of the most likely future spot rate as there are people doing forecasts. However, in a study the choice has to be made between the current spot rate and the forward rate for the forecasted period. If the interest rates of the two currencies are assumed to be equal, the forward rate equals the spot rate as given by Equation 1.

$$\frac{\Delta S}{S_0} = X_2 \sim N(0, \sigma_{\text{impl.}}) \quad (12)$$

and therefore

$$S = S_0 + X_2 * S_0 = (1 + X_2) * S_0 \quad (13)$$

where

S_0 is the initial spot rate

S is the spot rate at the end of the period

5.3. Simulation formulas

The cash flow in each scenario is a sum of the cash flows from the underlying risk position, the forward hedge and the option hedge. The cash flow from the underlying position depends on the change in FX rates as well as on whether the tender is accepted. To focus on the FX risk, the cash flow of the underlying position is defined to be the change in the business cash flow resulting from FX changes – not the total cash flows of sales and expenses. In other words, in scenarios where the tender is not accepted risk is measured against zero and in scenarios where the tender is accepted risk is effectively measured against the budgeted sales margin.

The cash flows from the forward and option hedges depend – in addition to the FX market change – on the hedge ratios.

The cash flow in each scenario for any hedging strategy is given by:

$$CF_{sc} = t * CF_{FX} + h_{FWD} * CF_{FWD} + h_{OPT} * (CF_{OPT} - p^{FUT}) \quad (14)$$

where

t is a binary variable with value 0 if tender is not accepted and value 1 if tender is accepted

CF_{FX} is the change in the business cash flows resulting from FX market, as given by Equation

h_{FWD} is the hedge ratio for the forward hedge

CF_{FWD} is the cash flow at the maturity of the forward, as given by Equation 2

h_{OPT} is the hedge ratio for the option hedge

CF_{OPT} is the cash flow at the maturity of the option, as given by Equation 7

p^{FUT} is the future value of the option premium (at the maturity of the option)

CF_{FX} is given by

$$CF_{\text{FX}} = n * \left(\frac{1}{S} - \frac{1}{S_0} \right) \quad (15)$$

where

n is the nominal amount of the currency denominated tender

S_0 is the spot rate at the time of pricing the tender

S is the spot rate at the maturity of the tender, as given by Equation 13

Using Equation 12, the expected value for CF_{FX} , CF_{FWD} and CF_{OPT} – and thus for CF_{SC} – is zero.

5.4 Other simulation settings

The calculations are done using the following assumptions.

Maturity of the tender:	three months
Nominal of the tender:	\$10 million
Interest rate of home currency:	5%
Interest rate of foreign currency:	5%
Initial FX rate:	1,2500
Forward FX rate:	1,2500
FX rate implied volatility:	9%
Probability level in CFaR calculations:	5%

Simulations are run in Excel using @Risk software. The outcome for each hedging strategy is simulated 10 000 times.

6. Analysis of results

6.1 Hedging with forwards

Table 6 lists the results when hedging is done only with forwards. The optimal hedge ratio increases almost in line with the acceptance probability. When the acceptance probability is very small no hedging should be done because that would only create risk. On the other hand when the tender is almost certainly accepted 100% should be hedged. If the acceptance probability is 50%, approximately 50% should be hedged. Obviously, the tender is either accepted or not so hedging 50% is always wrong by 50%. Therefore Cash-Flow-at-Risk is greatest here – almost 300 000 EUR. With 50% acceptance probability, hedging 0% or 100% would, however, create even bigger risks because then there is a 50% probability that the open position is 100% - in the first case because of an accepted tender and in the latter because of a rejected tender.

Acceptance probability	5%	10%	15%	20%	25%	30%	35%	40%	45%	
Hedge ratio / Forwards	0%	0%	10%	15%	20%	25%	30%	35%	35%	
CfaR (in mEUR)	0,000	0,000	-0,131	-0,200	-0,234	-0,257	-0,277	-0,286	-0,293	
	50%	55%	60%	65%	70%	75%	80%	85%	90%	
	45%	50%	60%	65%	65%	70%	80%	90%	100%	
	-0,296	-0,293	-0,289	-0,277	-0,264	-0,244	-0,206	-0,143	-0,007	0,000

Table 6: Optimal forward hedging strategies and CFaR

CFaR for 50% acceptance probability and various forward hedging strategies is presented in Table 7. What can be noted here is that close to the optimal level 5 %-point differences in hedge ratio have very small effects on the CFaR figure – only 1000 EUR.

Acceptance probability	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	
Hedge ratio / Forwards	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	
CfaR (in mEUR)	-0,430	-0,409	-0,387	-0,366	-0,344	-0,325	-0,309	-0,301	-0,297	-0,296	
	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	
	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	
	-0,297	-0,301	-0,307	-0,322	-0,344	-0,369	-0,393	-0,418	-0,442	-0,467	-0,491

Table 7: CFaR for 50% acceptance probability and forward hedges

6.2 Hedging with options

Table 8 lists the results when hedging is done only with options. Now, the optimal hedge ratio is either 0% or 100% - never anything else. If acceptance probability is 20% or greater, 100% should be hedged. This is simply because at these levels of acceptance probability the CFaR of the underlying position becomes greater than the premium cost of the option. Since we are using at-the-money options, the maximum loss with an option hedge equals the premium.

Acceptance probability	5%	10%	15%	20%	25%	30%	35%	40%	45%
Hedge ratio / Options	0%	0%	0%	100%	100%	100%	100%	100%	100%
CfaR (in mEUR)	0,000	0,000	-0,140	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222
	50%	55%	60%	65%	70%	75%	80%	85%	90%
	100%	100%	100%	100%	100%	100%	100%	100%	100%
	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222

Table 8: Optimal option hedging strategies and CFaR

6.3 Hedging with forwards and options

Table 9 lists the results when hedging can be done using both forwards and options. Interestingly, there are no strategies involving a combination of the instruments. If acceptance probability is low, below 25%, the optimal strategy is the respective forward strategy. With acceptance probabilities from 25% to 75% optimal is to hedge 100% with options. Finally, with high acceptance probabilities forwards strategies are again optimal.

Acceptance probability	5%	10%	15%	20%	25%	30%	35%	40%	45%
Hedge ratio / Forwards	0%	0%	10%	15%	0%	0%	0%	0%	0%
Hedge ratio / Options	0%	0%	0%	0%	100%	100%	100%	100%	100%
CfaR (in mEUR)	0,000	0,000	-0,131	-0,200	-0,222	-0,222	-0,222	-0,222	-0,222
	50%	55%	60%	65%	70%	75%	80%	85%	90%
	0%	0%	0%	0%	0%	0%	80%	90%	100%
	100%	100%	100%	100%	100%	100%	0%	0%	0%
	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222	-0,206	-0,143	-0,007
									0,000

Table 9: Optimal hedging strategies and CFaR, using both forwards and options

Figure 4 below sums up the results.

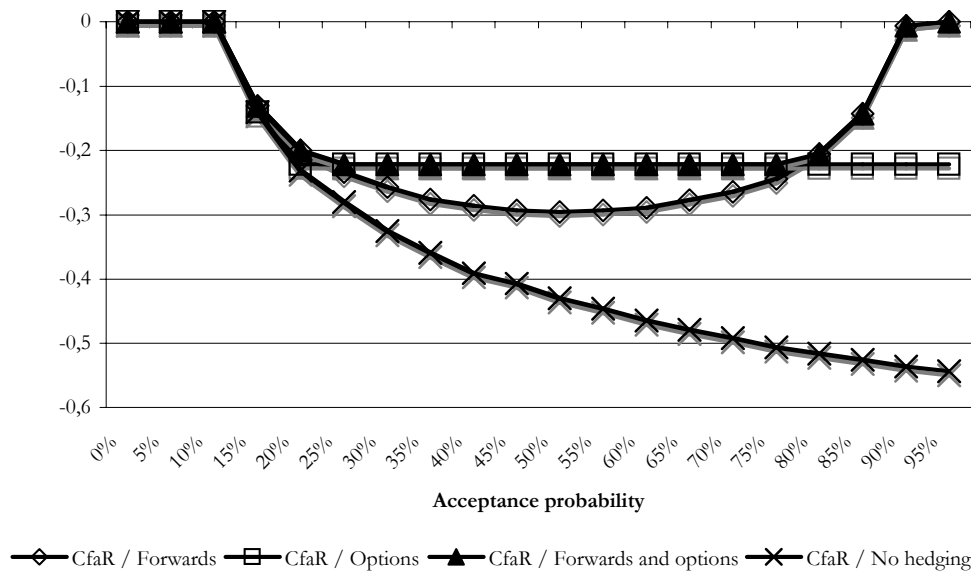


Figure 4: Optimal hedging strategies and CfaR

6.4 Implications for hedging decisions

In a real life tender process it is impossible to know what the exact acceptance probability is. Keeping this in mind, the results above are very convenient. While 231 different hedging strategies were studied, the optimal solution includes only seven of them. Further, one can come very close to the optimal hedge using only three different strategies – hedging nothing, hedging 100% with options or hedging 100% with forwards. The difference in CfaR between this and the optimal set of strategies is shown in Table 10. The difference in CfaR is on average only 3300 EUR and in the worst case 22 000 EUR. For hedging purposes, it therefore suffices to know whether the acceptance is unlikely (probability of less than 20%), possible (20% to 80%) or very likely (more than 80%).

Acceptance probability	5%	10%	15%	20%	25%	30%	35%	40%	45%
Hedge ratio / Forwards	0%	0%	0%	0%	0%	0%	0%	0%	0%
Hedge ratio / Options	0%	0%	0%	100%	100%	100%	100%	100%	100%
CfaR / three strategies	0,000	0,000	-0,140	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222
CfaR / optimal	0,000	0,000	-0,131	-0,200	-0,222	-0,222	-0,222	-0,222	-0,222

	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
Hedge ratio / Forwards	0%	0%	0%	0%	0%	0%	0%	100%	100%	100%
Hedge ratio / Options	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%
CfaR / three strategies	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222	-0,159	-0,007	0,000
CfaR / optimal	-0,222	-0,222	-0,222	-0,222	-0,222	-0,222	-0,206	-0,143	-0,007	0,000

Table 10: CfaR choosing only from three strategies vs. CfaR with optimal strategies

7. Ideas for future research

This study focused on hedging one single tender. Depending on the industry sector a company may at the same time have several open tenders in its portfolio. Hedging a portfolio of currency denominated tenders would be one interesting area of further research. In a large portfolio, the outcome is no more 0% or 100% but some combination of the accepted and non-accepted tenders.

Another interesting area for further research would be to study other hedging instruments beyond forwards and vanilla options or to even develop new ones for hedging tenders. Patel (2001) discusses an option structure where the option may only be exercised if the tender is successful. In this strategy there is a small initial premium upfront and then a success premium, which is paid only if the underlying tender is successful. This hedging strategy has not, however, yet gained ground – partly because it is very difficult for the seller to hedge the risk created by offering the strategy, and therefore to price.

The model developed could also be extended to several periods. A tender process may often consist of several phases or the company may otherwise gain a better understanding of the acceptance probability as time progresses. The possibility to modify the hedge later with more exact information might have an effect on the optimal hedging strategies.

Another example of a model extension is to make acceptance probabilities dependant on currency rate changes. Weakening of the sales currency would most likely increase the acceptance probability while a strengthening would decrease it – if not by decreasing the competitiveness of the tender then because the purchasing company could renew the tender process in hopes of getting better prices. Allocating the costs of hedging into the pricing of tenders could also be a possible area of model extensions.

Finally, other risk measures beyond Cash-Flow-at-Risk could be tested, as well as Cash-Flow-at-Risk using other probability levels. Different risk measures may lead to different hedging strategies. At-Risk measures are only one option, though perhaps the most widely used.

References

- Andren, N., Jankensgård, H., Oxelheim, L. 2005 Exposure-based Cash-Flow-at-Risk under Macroeconomic Uncertainty. *Forthcoming in Journal of Applied Corporate Finance*
- Bank of America. 2004. *The 2004 FX Risk Management Survey*
- Bodnar, G.M., Hayt, G.S., Marston, R.C. 1998. 1998 Wharton Survey of Financial Risk Management by US Non-Financial Firms. *Financial Management* **27** No.4, 70-91
- Culp, C.L., Miller, M.H., Neves, A.M.P. 1998. Value-at-Risk: Uses and Abuses. *Journal of Applied Corporate Finance* **10** No.4
- Froot, K.A., Scharfstein, D.S., Stein, J.C. 1993. Risk Management: Coordinating Corporate Investment and Financing Policies. *Journal of Finance* **48**, 1629-1658
- Froot, K.A., Scharfstein, D.S., Stein, J.C. 1994. A Framework for Risk Management. *Harvard Business Review* **72** No.6, 91-102
- Garman, M.B., Kohlhagen, S.W. 1983. Foreign Currency Option Values. *Journal of International Money and Finance* **2**, 231-237
- Geczy, C., Minton, B.A., Schrand, C. 1997. Why Firms Use Currency Derivatives. *Journal of Finance* **52** No.4, 1323-1354
- Hull, J.C. 1997. *Options, Futures and Other Derivatives* Prentice Hall, New Jersey
- Jorion, P. 1997. *Value at Risk* McGraw-Hill
- LaGattuta, D., Stein, J.C., Usher, S.E., Youngen, J. 2001 A Comparables Approach to Measuring Cashflow-at-Risk for Non-Financial Firms. *Journal of Applied Corporate Finance* **13** No.4, 8-17
- Luenberger, D.G. 1998 *Investment Science* Oxford University Press, New York
- Markowitz, H.M., 1959. *Portfolio Selection* Wiley, New York
- Miller, K.D., Leiblein, M.J. Corporate Risk-Return Relations: Returns Variability versus Downside risk, *Academy of Management Journal*, **39**, 91-122
- Nordea. 2004. *Financial Instruments* GCS media, Oslo
- Patel, N. 2001. Try a little tender hedge *Risk* July 2001, 32-34
- RiskMetrics, 1999. *CorporateMetricsTM Technical Document*, RiskMetrics Group, New York
- Stulz, R.M. 2002. *Risk Management and Derivatives* Thomson South-Western

Stulz, R.M. 1996. Rethinking Risk Management. *Journal of Applied Corporate Finance* **9**
No.3, 8-24

Stulz, R.M. 2004. Should We Fear Derivatives? *National Bureau of Economic Research*
Working Paper No. 10574