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Corporate Risk Management with Currency Derivatives

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1. Introduction

Options and other derivatives have become more and more popular in the financial world lately and especially from the early 1990's to the present. The financial markets have been deregulated all over the world and new financial instruments are invented and introduced all the time to fulfill the growing demand for sophisticated financial tools. Although financial derivatives tend to be more complex than other types of investments like direct investment in stocks or in mutual funds, there is still a huge demand for them.

According to the principles of finance, the amount of risk carried is directly proportional to the profits (more risk has to be carried if the investor prefers a higher return), and the same holds for the derivatives. Nowadays the operators in the financial markets have more assets to invest than ever before and they are willing to bear an increased risk if there are possibilities for bigger profits in the future. Thus, when the information and knowledge of the possibilities in the complex international financial markets increase, also the demand for advanced financial instruments rises.

In this paper, we will concentrate on currency risk management in our medium sized case corporation. The main interest is on forward and option contracts with illustrative example cases. The case corporation is a Finnish import/export company which specializes in higher technology machine products. Most of the case corporation's purchases are made in a foreign currency (in Swedish krona, SEK) while all the sales are in Euros. Therefore, depending on the period of time between the decision of purchase and the actual payment, the corporation has an open risk position for the SEK/EUR exchange rate. With illustrative examples, the corporation's actual financial transactions will be back-tested to study how effective the outcome of hedging can be in corporation's real-life situations. The goal is to determine if a Finnish medium sized company which actively trades in a foreign currency can benefit from active hedging strategies with currency derivatives.

First, the theory of derivatives will be discussed. Option pricing theory and model are presented for equity and currency options. Also, the main characteristics and differences between futures and forwards are discussed. Second, case corporation analysis includes earlier research on hedging situations and also our case corporation's presentation. Different strategies for 3 different cases are studied to find the possible benefits of hedging in this corporation. Finally, the cases' results will be shown and summarized in the last chapters.

2. Theory of Currency Derivatives

The most common types of derivatives are options, forwards and futures. The most typical example is a simple stock option where an underlying asset is a stock of a company. In general, derivatives are financial instruments whose price is *derived* from some other financial asset (the underlying commodity or asset) (Hull 2005). Although derivatives are often seen as instruments of a speculator who looks for the opportunity of greater profits, we must recall that originally derivatives were used to hedge from the risk (futures trade with commodities in the 19th century).

Historically, derivative contracts have been used to lock in the price of a commodity (for example grain or other farming product) and determine the price of the next harvest beforehand. This transaction transferred the risk of possible changes in the market price (hedging from the volatility) to a willing participant who wants to bear the risk (Hull 2005). In practice, the farmer is buying a future which allows him to sell a certain amount of grain with a certain price in the future. With a forward and a future he is obliged to deliver the asset and there are no costs in entering the contract. For an option, there is a premium which he has to pay for the writer. Depending on the market price in the future, the farmer will make profit or loss (If the price turns out to be more than the specified rate in the contract, the farmer loses).

2.1. Introduction to Derivatives

The most important fact that separates options from forwards and futures is the characteristic that the owner of the option has a right to sell or buy the underlying asset but he is not obliged in any way to do so. The purchaser of an option contract has to pay a premium for the writer (an option writer demands a higher premium for the increased risk compared to a forward/future). Another difference is the specified form. Futures are specified contracts (specified form allows high liquidity since they are traded on exchanges) unlike forwards (OTC, over-the-counter market) and options (traded on both) which can be tailored to suit one’s needs.

Although derivatives have been used at least for centuries already, there have not been any conclusive models to determine option prices until the year 1973 when Fischer Black and Myron Scholes introduced their model on option pricing (Black, Scholes. 1973, Hull. 2005). Notable is that the simpler and not so accurate binomial model was introduced as late as in 1979 (Cox et al. 1979). Basically, the binomial pricing model is a numerical method of pricing an option contract. It creates a tree of all possible option prices towards the expiration. Although the binomial model is very useful on pricing the American options it will not be discussed thoroughly and the main concern will be on the Black-Scholes model and on the models derived from it. The literature is extensive in area of option pricing theory and many thorough books exist. In this paper, John C. Hull's "Options, Futures and Other Derivatives", Alan C. Shapiro's "Foundations of Multinational Financial Management" and Robert L. McDonald's "Derivatives Markets" are used as a basis for the next section.

2.2. Option Pricing

2.2.1. Equity Options

The original Black-Scholes model (sometimes called as a Black-Scholes-Merton model) was developed for European equity options. The model assumes that the stock does not pay any dividends and the option can only be exercised on maturity. Therefore the original model can not be used on pricing American options if the underlying stock pays dividends. Other restrictions also exist,

- Continuously compounded returns are normally distributed
- There are no transaction costs
- Short-selling is allowed
- There are no riskless arbitrage opportunities

Original paper by Black & Scholes (1973) assumed that the volatility and the risk-free rate are constant but the model can be also used with changeable variables. Later, the model has been slightly modified to be able to price options with different underlying assets. The following equation is for a simple European call option:

$$C = SN(d_1) - Xe^{-r(T-t)}N(d_2) \qquad (2.1)$$

Where,

$$d_1 = \frac{ln(\frac{S}{X})+(r+\frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

C = Call price

S = Share price (price of an underlying equity)

X = Strike price (exercise price)

r = Continuously compounded interest rate

σ = Volatility of an underlying equity

N = Standard normal cumulative distribution function

$T-t$ = The time until maturity in years

The function N(x) is the standard normal cumulative distribution function. The function $N(d_1)$ is the change in the option price when the price of an underlying asset changes n units. $N(d_2)$ is the probability of the option contract being in-the-money at expiration date. The volatility is an important variable in the equation since the more volatile the underlying asset (the currency rate) is, the more probably it will be in-the-money at maturity. Some scholars argue that the volatility changes over time and correlates positively with the volume (Bjønnes et al.

2003). Volatility tends to change over time with the amount of traders conducting transactions with heterogeneous beliefs of future fluctuation and with asymmetric information.

The price for put option can be derived from put-call parity equation (2.2) which shows the relation between call and put options with the same exercise price and maturity,

$$P = C - S + Xe^{r(T-t)} \qquad (2.2)$$

Where,

P = Put option price

When C is solved from put call parity equation and added into the equation 2.1, it simplifies in to a put option price model:

$$P = -SN(-d_1) + Xe^{-r(T-t)}N(-d_2) \qquad (2.3)$$

2.2.2. Currency Options

A slightly modified pricing model is needed for currency options (Garman & Kohlhagen 1983, McDonald 2006). The following currency call option model is known as the Garman-Kohlhagen model,

$$C = FXe^{-r_f(T-t)}N(d_1) - Xe^{r_d(T-t)}N(d_2) \qquad (2.4)$$

Where,

$$d_1 = \frac{ln(\frac{FX}{X})+(r_d-r_f+\frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{(T-t)}}$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

FX = Current spot rate (foreign/domestic)

X = Strike rate (exercise rate)

r_f = Foreign currency risk free rate

r_d = Domestic currency risk free rate

σ = Volatility of the currency rate

N = Standard normal cumulative distribution function

$T-t$ = The time until maturity in years

The model for a currency put option is as follows:

$$P = -FXe^{-r_f(T-t)}N(-d_1) + Xe^{-r_d(T-t)}N(-d_2) \quad (2.5)$$

In this paper, an Excel model is used to estimate the currency call option prices implied by the Garman-Kohlhagen model.

2.3. Forwards and Futures

With forwards and futures, the future price of an asset (or currency rate) is already set and both parties (the writer and the purchaser) are obliged to carry out the contract and to split the risk. It has to be always remembered that the future/forward market is a zero-sum game, and for every winner, there is always a loser (Hull 2005).

2.3.1. Differences Between Forwards and Futures

Although forward and futures contracts are highly similar and used in the same context, some major differences exist. First, forward contracts can be tailored to suit one's needs (size and maturity) while futures contracts are highly standardized in size and maturity. Therefore futures contracts offer more liquidity and easier trading in future exchanges where a clearinghouse works as a middleman between the two parties (Fabozzi et al. 2002). On the contrary, forward contracts are traded in the over-the-counter (OTC) markets which offer trading directly between two parties. There are virtually no secondary markets for forward contracts. Some markets might exist but trading for specialized contracts can be difficult.

In futures trade the default risk of the other party will be transferred to a middleman unlike in the forward contract, where the risk of other party not honoring the contract exists. Also the clearinghouse makes it easier for two parties to get out of the futures contract. The two parties do not need to cancel their original contract with each other; instead, the unwilling party will sell an identical contract which will offset the original one.

Second, they also differ on the settlement. Forwards are settled once at maturity and depending on the price of an underlying asset; the purchaser/writer will make profit or loss. Futures are settled daily depending on the underlying price (marking to market). The clearinghouse will require the purchaser to deposit a certain amount of funds into a *margin account* (a percentage of the contract size). At the end of the each trading day, the clearinghouse requires the account to be adjusted according to the market movements. So, if the price of an underlying asset increases, the clearinghouse will return some of the initial margin already deposited if the price falls the purchaser must increase his initial margin (Hull 2005, Fabozzi et al. 2002).

2.3.2. Forwards & Futures Pricing

The pricing for forwards and futures is fairly simple and the same model can be used to determine the both. Simply, the present value is compounded with the risk-free rate to the maturity. Forwards and futures pricing model is as follows (equation 2.6):

$$F(t) = S(t)(1+r)^{(T-t)} \quad (2.6)$$

Where,

$F(t)$ = Value of a forward/futures contract (forward price)

$S(t)$ = Present value of a forward/futures contract (nominal value)

r = Risk-free rate of return

$T - t$ = The time until maturity in years

The forward price must be in the equilibrium, otherwise there are arbitrage opportunities and riskless profit. In other words, the investor has two possibilities (Fabozzi et al. 2002),

1. he can buy the currency today at spot rate and invest it with a risk-free rate until maturity or,
2. He can enter into a forward contract immediately and lock in the rate.

Both possibilities must produce the same outcome; otherwise there are arbitrage possibilities and riskless profits in the market. For example, let us assume that a spot rate is now 9.3500 SEK/EUR and our corporation needs to pay 98,325 SEK in one year from now. STIBOR is 3.5 % and EURIBOR is 4.0 %. Therefore the forward rate is 9.3050 SEK/EUR.

If the forward rate was for example 9.1800 SEK/EUR, an arbitrager could borrow 10,160.43 Euros at a rate of 4.0 % and buy 95,000 SEK and deposit it with a rate of 3.5 %. Then he would enter into a long Euro forward contract at rate of 9.1800 SEK/EUR (contract size 10,160.43 EUR * 1.04 = 10,566.85 Euros).

In a year he would get 98,325 SEK (95,000 SEK * 1.035) from his deposit. He needs to pay 10,566.85 EUR * 9.1800 SEK/EUR = 97,003.68 SEK. Therefore, he gains a riskless profit of 98,325 SEK – 97,003.68 SEK = 1,321.32 SEK**.** An arbitrage possibility also exists if the forward rate is for example 9.4000 SEK/EUR. An arbitrager could borrow 95,000 SEK at a rate of 3.5 % and enter into a long SEK forward contract (size 98,325 SEK) at a rate of 9.4000. Also he would transfer 95,000 SEK to 10,160.43 Euros and invest it at rate of 4.0 % for the maturity. After a year he needs to pay 98,325 SEK and he gets 10,566.85 EUR. He pays 98,325 SEK / 9.4000 SEK/EUR = 10,460.11 Euros for the contract and therefore this arbitrage creates a risk-free profit of 10,566.85 EUR – 10,460.11 EUR = 106.74 Euros. The equation for currency forwards (an example presented above) is (equation 2.7),

$$F(t) = S(t)e^{(r-r_f)T} \qquad (2.7)$$

Where,

r = Domestic risk-free rate
r_f = Foreign risk-free rate

The payoff to long forward contract is the value of the contract in the end of the maturity and can be presented in the following way (McDonald 2006),

$$\text{Payoff} = \text{Spot Price at Expiration - Forward Price} \qquad (2.8)$$

And for the short forward the payoff is,

$$\text{Payoff} = \text{Forward Price - Spot Price at Expiration} \qquad (2.9)$$

3. Case Corporation Analysis

3.1. Corporation Profile

The case corporation is a Finnish medium sized import/export company specialized in higher technology machine products. The turnover for last year was over 2 million Euros and the main market area is Finland, while the corporation also operates in Continental Europe. Corporation's all sales are currently in Euros while most of the purchases are in Swedish krona and therefore it is exposed to some currency rate risk.

How can we determine what our company's exposure is then? According to Børsum (2005) an estimation of company's exposure is difficult but two ways exist.

a) An exposure is determined for all individual cash flows in the corporation and some cash flows will eliminate each other out (natural hedging)
b) Historical data can be used to predict the future exposure to currency rate movements

It can easily be seen how difficult an estimation of exposure based on company's all cash flows in a foreign currency can be, especially when the company size and/or foreign currencies used increase. The second method has its obvious problems also. One can ask how reliable a historical data can be as a predictor of future currency rate movements. In our case we could use the first method of estimation quite effectively since the amounts of individual cash outflows are not too extensive (around 60 transactions and 700,000 Euros per year). Also, due to the nature of this paper, a thorough estimation is not necessary since the most typical cases of corporation's cash outflows can be used to illustrate the usefulness of derivatives hedging.

3.2. Cases

Table 3.1 describes the operational cash outflows that are common for our case corporation. Three cases are selected for this analysis and although these figures are not exactly tremendous, they are based on real transactions and were chosen to present accurately the financial challenges that our corporation faces.

Table 3.1

Case	Contract Size in SEK	t	T	T - t in Days	T - t in Years
1	116,000	12/20/2006	7/20/2007	212	0.581
2	88,000	2/6/2007	8/31/2007	206	0.564
3	93,000	6/5/2007	9/24/2007	111	0.304

Many different types of hedging strategies exist. Loderer & Pichler (2000) list four different strategies:

a) Avoid risk
b) Transfer of production in to a foreign region
c) Pass the risk to others
d) Choose to bear the risk

Currency rate risk can be avoided by trying not to conduct any trade in a foreign currency. Like Børsum (2005) argues, this can be extremely difficult in an open economy like Norway (or Finland). The production could be transferred in to the foreign country also, thus eliminating the need of constant transfer of funds from domestic to a foreign currency. For our company a transfer of production is not an option since it already operates in the area of European Monetary Union (EMU). The inner market of European Monetary Union countries provides a vast amount of possible customers without any currency rate risk involved and our corporation can fully benefit from it.

Copeland (2005) discusses about the advantages and disadvantages of such monetary union. He divides these to micro and macroeconomical functions. One common currency reduces daily transaction costs but also creates certainty and stability in the markets. He also argues that the significance of reducing the volatility and the currency rate conversion costs are trivial and that the EMU is not going to be a success. His point of view is from the bigger countries side like France or Germany but he does not discuss this matter on behalf of a small or medium sized corporation which conducts international trade in the modest scale in the EMU area. A corporation, like our example, benefits hugely from using a bigger and more stable currency like Euro instead of a highly volatile Finnish Markka. When taking into account the incapability of Finland's Interbank to maintain a sustainable Keynesian economic growth without a need of devaluation of domestic currency in constant cycles, we understand how important the EMU system is for small corporations. Although Copeland lists many benefits on a common currency, he still agrees that one world currency is not necessarily a possibility, mainly due to nationalistic movements.

The differences between Sweden and Finland are very small and no immediate benefits can emerge from such action. The risk can also be transferred to other party by negotiating a purchase contract in Euros instead of SEK. This could be very useful but it is not always possible and depends greatly on our company's negotiation skills. Lastly, the company can choose to bear the risk taken. This is the actual situation in our case corporation at the moment since it does not conduct any kind of hedging.

Although there is an open risk position, the corporation already avoids risk by negotiating the contracts and selling all its merchandise in Euros. Therefore there is no need for constant hedging on income. According to these three examples, our corporation has four different solutions:

a) Remain unprotected during the exposure and purchase the required amount of SEK at spot rate in time T
b) Buy EUR forward contracts and immediately hedge from the currency rate fluctuation risk by locking in the currency rate
c) Hedge from the risk with options contracts and maintain a possibility of benefiting from the favorable market movements
d) Use partial hedging strategies (50 % of contract size hedged)

The first one exposes corporation fully to currency risk while strategies b and c hedge the position completely (although there is an option not to exercise the contract on c). Naturally, 50 % hedging will remove only a portion of the risk. Sometimes partial hedging is more advisable if the volatility of currency rate is not extremely high. The hedging costs will be reduced significantly while the risk only increases moderately.

3.3. Forward Strategies

The corporation has three cases with different maturities. In all situations we need a certain amount of SEK to pay our purchases at a specified moment in the future. The main objective is to lock in the currency rate instead of some speculative profits. Therefore in this example the SEK/EUR rate is locked in to a current spot rate (time t, currency rate today). The corporation wishes to maintain the current situation.

3.3.1. Full Hedge

In the first case the corporation,

1. Enters into a long SEK forward contract worth of 116,000 SEK (July 2007 212-day long position) when the spot rate is 9.0095 SEK/EUR (20th of December). The corporation is obliged to buy 116,000 SEK in July 2007. The forward rate F_0 is 8.9856 SEK/ EUR and calculated with an equation 2.7. The calculations are presented below (note that in this case r = 3-month STIBOR and r_f = 3-month EURIBOR, continuously compounded),

$$F_0 = 9.0095e^{(0.031818-0.03640)0.581}$$

2. By 20th of July the spot rate has increased to 9.1665 (the Swedish krona value has declined). The corporation would pay 116,000 SEK / 9.1665 = 12,654.78 Euros in the spot market. The corporation is obliged to honor the contract and pays 116,000 SEK / 8.9856 SEK/EUR = 12,909.54 Euros instead.
3. The payoff is -254.76 Euros (=12,654.78 – 12,909.54). The hedging is not effective and company loses money since it is obliged to honor the contract with an agreed rate. The negative payoff is the cost of hedging from the currency rate risk.

With the same logic, the second case (6th of February until 31st of August, 88,000 SEK) and the third (5th of June until 24th of September, 93,000 SEK) produce the following results, respectively,

1) The corporation enters into a long SEK forward contract (206-day contract) with a forward rate of 9.1243 SEK/EUR (6th of February spot rate is 9.1425 SEK/EUR).
2) By 31st of August the SEK value has decreased against EUR and is now 9.3585. The contract is carried out and the corporation pays 88,000 SEK / 9.1243 SEK/EUR = 9,644.58 Euros.
3) In the spot market the corporation would buy 88,000 SEK at 9.3585 which equals to 9,403.22 Euros. The forward payoff is –241.36 Euros (= 9,403.22 EUR – 9,644.58 EUR).

And the final case,

1) The corporation enters into a long SEK forward contract (111 days of maturity) when the spot rate is 9.3200 SEK/EUR (5th of June). The contract is worth 93,000 SEK and the forward rate is 9.3063 SEK/EUR.
2) The contract is carried out at 24th of September. The corporation pays 93,000 SEK / 9.3063 SEK/EUR = 9,993.23 Euros.
3) The spot rate is 9.1850 SEK/EUR. The unprotected position would cost 93,000 SEK / 9.1850 SEK/EUR = 10,125.20 Euros. The payoff is 10,125.20 EUR - 9,993.23 EUR =

131.97 Euros. The market movement (the devaluation of Swedish krona) is favorable and the forward contract is profitable.

3.3.2. 50 % Hedge

The situation with 50 % hedging is exactly the same but the corporation decides not to enter completely into the forward contract. Usually this is due to the amount of costs. If the purchaser of a contract does not believe in vast and rapid changes in the price of an underlying asset, he may choose to hedge some certain specified percentage of exposure. For example for the case one,

1. The corporation has entered into a long 50 % SEK forward contract. The contract size is therefore 58,000 SEK (50 % of 116,000 SEK). Another 58,000 SEK part will be bought from the spot market at maturity. F_0 is still 8.9856 SEK/EUR.
2. The amount corporation pays for the hedged part is 58,000 SEK / 8.9856 SEK/EUR = 6,454.77 Euros. Another part is bought from the spot market at 9.1665 SEK/EUR. Therefore, the other half costs 58,000 SEK / 9.1665 SEK/EUR = 6,327.39 Euros.
3. The total amount paid is 12,782.16 Euros (= 6,454.77 EUR + 6,327.39 EUR) which indicates that the effective currency rate is 9.0751 SEK/EUR (= 116,000 SEK / 12,782.16 EUR).

For cases two and three,

1. Contract sizes are 44,000 and 46,500 SEK and forward rates are 9.1243 and 9.3063 SEK/EUR.
2. The corporation pays 4,822.29 Euros and 4,996.62 Euros (44,000 SEK / 9.1243 SEK/EUR and 46,500 SEK / 9.3063 SEK/EUR) for the hedged parts. The spot rates are 9.3585 SEK/EUR and 9.1850 SEK/EUR. The corporation pays 4701.61 Euros and 5,062.60 Euros for the other halves.
3. The total amounts paid are 9,523.90 Euros and 10,059.22 Euros (= 4,822.29 Euros + 4701.61 Euros and 4,996.62 Euros + 5,062.60 Euros). The effective currency rates are

88,000 SEK / 9,523.90 EUR = 9.2399 SEK/EUR and 93,000 SEK / 10,059.22 EUR = 9.2453 SEK/EUR.

In this case, the 50 % hedging strategy helps to lower the total costs caused by the devaluation of Swedish krona. In other words, our corporation benefits from the favorable market movements. Table 3.2 summarizes the hedging costs for both strategies and for all cases,

Table 3.2

Case	Contract Size in SEK	Realized Rate	Spot Rate at Time T	Total Costs in Euros
1a	116,000	8.9856	9.1665	12,909.54
2a	88,000	9.1243	9.3585	9,644.58
3a	93,000	9.3063	9.1850	9,993.23
1b	58,000	9.0751	9.1665	12,782.16
2b	44,000	9.2399	9.3585	9,523.90
3b	46,500	9.2453	9.1850	10,059.22

Cases classified as “a” are fully hedged while cases with a label “b” are 50 % hedged. The case 1a has the worst rate while case 3a has the most favorable one. Since the cases 1 and 2 face unfavorable market movements (the spot transaction is more effective and the locked-in rate is more expensive, our corporation pays more Euros if the krona is quoted at a lower rate), the 50 % hedging helps to cut some losses. It is a good trade-off for all situations. It is always easy to back-test these kind of situations and see what is the outcome and suggest the best solution. But in the moment when hedging decision is made, there is no specific information on future currency rate movements, only educated guesses. 50 % hedging seems to smooth effectively not only the profits but also the losses obtained with forwards contracts. Therefore it would be advisable to start using 50 % hedging in our example corporation. The fully locked-in currency rate seems to be too stiff way to hedge from the currency rate risk and could lead to losses. Perhaps bearing some risk could benefit the corporation in the long run.

3.4. Option Strategies

The corporation needs to pay certain amount of SEK in the future, therefore it can hedge from the exposure with call options (the purchaser has a right but not an obligation to buy a specified amount of SEK in a specified moment in future). In each case the spot rate equals the strike rate since the goal is to lock in the rate and eliminate the risk rather than to speculate. Table 3.3 presents the required variables to Garman-Kohlhagen currency option pricing model (equation 2.4):

Table 3.3

Variables	Case 1	Case 2	Case 3
Spot rate	0.11099	0.10938	0.10730
Strike rate	0.11099	0.10938	0.10730
Domestic risk-free rate	3.640	3.714	4.043
Foreign risk-free rate	3.181	3.361	3.560
Time period	0.581	0.564	0.304
Volatility	0.041435367	0.051146438	0.035616157

Note that the currency rates used in this section are EUR/SEK (indirect quotation). Domestic risk-free rate is a 3-month EURIBOR (European Interbank Offered Rate) on a time t and foreign risk-free rate is a 3-month STIBOR (Stockholm Interbank Offered rate) also at time t. Time period (maturity of the contract) is in years and already calculated and presented earlier in Table 3.1. Although these variables are not constant, they can be easily obtained from statistic databases (interbank offered statistics / Datastream) and time until maturity can be easily calculated with Excel.

3.4.1. Volatility Estimation

The most challenging variable to be estimated is the volatility of an underlying asset. Mainly, three different approaches exist (Hull 2005);

a) GARCH model
b) Implied volatility

c) Historical or statistical volatility

The GARCH (Generalized Autoregressive Conditional Heteroscedasticity) model calculates a weighted average of the underlying assets variation in the way that the most recent value gets a greater importance. The GARCH model tries to predict the future variable volatility. Due to the nature of this paper, the GARCH model is not discussed thoroughly**.**

Implied volatility is calculated from Black-Scholes equation with the known option price (market quotation). In other words, the Black-Scholes equation is presented backwards. Mathematically, the volatility is presented as a function of S_0, X, r, T and C (spot price, strike price, risk-free rate, maturity and call price) (Hull 2005). Volatility is solved from the original equation and when the market price of an option (call or put) is added, we get the *implied volatility*. Implied volatility is a market estimation of the future volatility of an option. In other words, implied volatility is the volatility which is implicit with the current option price. This volatility can be then used to price other options with the same underlying asset but a different strike price. There are few problems with this approach, especially with the options not traded actively. A problem emerges when market implied volatility needs to be calculated and the market is not efficient or traded actively. This analysis faced this problem also since SEK/EUR options are not traded as actively as for example USD/EUR options. The market price data for SEK currency options were not available in the wide basis; therefore historical data approach was used to estimate the volatility.

Historical volatility is relatively easy to measure. Only price time series data of an underlying asset and some Excel calculations are needed. In this paper, 30-day volatility is used to price the options. First, continuously compounded rates of returns (changes in currency rate) are calculated (equation 3.1) (McDonald 2006, Hull 2005).

$$r_{cc} = ln(P_T) - ln(P_t) = ln\frac{P_T}{P_t} \tag{3.1}$$

Where,

r_{cc} = Continuously compounded rate of return

P_T = Price of an underlying asset (currency rate) at time T

P_t = Price of an underlying asset (currency rate) at time t

The time series used is 30 days prior to the purchase decision (time t). After continuously compounded currency rate fluctuation is calculated, Excel can be used to determine the daily standard deviation. Mathematically standard deviation can be presented with the following equation:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(P_T - \bar{P}\right)^2} \quad (3.2)$$

Where,

σ = Standard Deviation

$$\bar{P} = \frac{1}{n}\sum_{i=1}^{n} P_i = \frac{P_1 + P_2 + \ldots + P_n}{n} \quad (3.3)$$

P_T = Price of an underlying asset (currency rate) at time T

The standard deviation calculated is the daily volatility (the currency rate quotations are in daily basis). For Black-Scholes model we need to use an *annualized volatility*. Note that we will not be using *annual volatility.* To annualize the volatility, we need to multiply daily standard deviation with a square root of actual trading days in a year. The equation can be presented mathematically in the following way (equation 3.4),

$$\sigma_{pa} = \sigma_d \sqrt{h} \qquad (3.4)$$

Where,

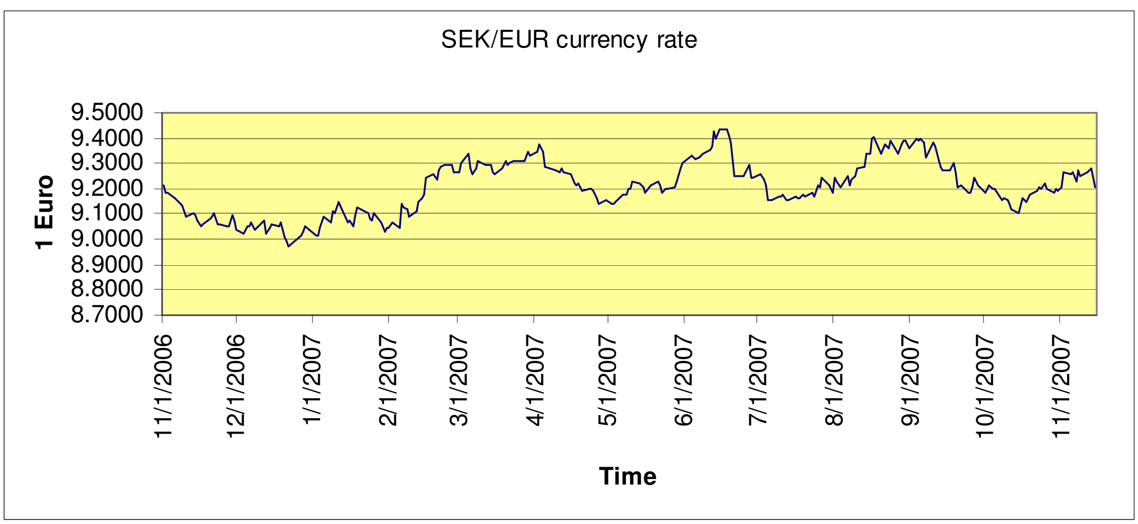
σ_{pa} = Annualized standard deviation

σ_d = Daily standard deviation

h = Interval

For daily time series data h = 252, since there are approximately 252 trading days in the year. With the same logic, h equals 52 or 12 for weekly or monthly time series data, respectively. Table 3.3 shows the 30-day historical volatilities obtained from the currency rate quotations data. The volatility differs from 3.5 % to over 5 %, depending on the case. Graph 3.1 presents the data graphically,

Graph 3.1



The lowest rate is just under 9 kronor while the highest is over 9.4. With these changes it is crucial to hedge against the risk.

3.4.2. The Costs of Hedging

After the volatilities are estimated, the call option can be priced. Table 3.4 shows the outputs of Garman-Kohlhagen model (equation 2.4). As mentioned above, $N(d_1)$ can be seen as a change in option price when the price of an underlying asset changes with n units. $N(d_2)$ represents the probability of options contract to be in-the-money at the time of maturity. There is not much difference with the $N(D_2)$ and since the strike rate equals the spot rate, the probabilities of options being in-the-money at maturity, are close to 0.50. Call prices differ a bit from 0.0009 (case 3) to 0.0018 (case 2) and present the price of hedging one krona in Euros.

Table 3.4

Output	Case 1	Case 2	Case 3
D_1	0.1030	0.0729	0.0877
D_2	0.0714	0.0345	0.0680
$N(D_1)$	0.5410	0.5291	0.5349
$N(D_2)$	0.5285	0.5138	0.5271
Call price	**0.0015**	**0.0018**	**0.0009**

The call price is known and we assume that the contract size is 116,000 units of currency (SEK) for case 1. Then, in this example, the contract size is specified for our corporation's needs (OTC market). The size could be determined beforehand on some fixed level, for example 10,000 units of foreign currency but this highly depends on the issuer (writer) of an option. For cases 2 and 3 we need to buy contracts worth 88,000 and 93,000 SEK, respectively. The costs of hedging (the premium) can be calculated in the following way (the underlying asset is krona and thus the call price is Euros of one krona),

- **Case 1:** (1 contract) * 0.0015 EUR/SEK * 116,000 SEK = 176.96 Euros.
- **Case 2:** 0.0018 EUR/SEK * 88,000 SEK = 154.47 Euros.
- **Case 3:** 0.0009 EUR/SEK * 93,000 SEK = 85.03 Euros.

The cost of hedging is less on case three than on cases one and two since the shorter maturity and slightly lower volatility. With the same logic, table 3.5 presents the costs of hedging for a 50 % hedge strategy. Naturally, the cost of hedging is half of the amount of full hedging strategy.

Table 3.5

	Case 1	Case 2	Case 3
50 %Contract Size	58,000	44,000	46,500
Spot Rate (SEK/EUR)	9.0095	9.1425	9.3200
Call Price	0.0015	0.0018	0.0009
Costs	88.48 EUR	77.23 EUR	42.52 EUR

3.4.3. Analysis Outcome

Depending on the market currency rate on maturity, the purchaser of an option contract decides if he wants to exercise the contract or not. If the maturity is longer than investor's hedging period, he can offset the position by buying an opposite contract (a call option worth of 116,000 SEK). In our example we bought call options on krona so we benefit if Swedish krona strengthens against Euro (the SEK/EUR rate decreases, 1 Euro is worth less kronor in future than now). Therefore if the Euro strengthens against krona, the corporation has to pay more Euros for their SEK purchase (an open position). Table 3.6 presents the actual market prices and our option contracts' strike rates.

Table 3.6

	Case 1	Case 2	Case 3
Market Quotation at T	9.1665	9.3585	9.1865
Option to Buy at (SEK/EUR)	9.0095	9.1425	9.3200
Profit	(220.52)	(222.16)	145.01
Profit (%)	(0.017)	(0.023)	0.015

As we can see, in cases one and two, the market movements have been unfavorable for our company and the corporation will not exercise the contracts. The amount needed will be bought from the spot market and the loss is the already paid premium. Our set strike rate by indirect quotation is 0.11099 EUR/SEK (1 / 9.0095 SEK/EUR) and when we add the premium which has to be taken into consideration before we gain from the contract, we get a break-even rate of 0.11252 ([12,875.30 EUR + 176.96 EUR] / 116,000 SEK).

The currency rate seems to be highly volatile and our needs for Swedish krona suit well the market movement in the case three. In cases one and two, the unprotected position seems to be the most effective one. In the third case our option hedging works better, our corporation can buy the amount needed with less Euros than from the spot market.

As noted above, the total cost of hedging is the Euro amount paid for the contract in the spot market and the added premium for the option contract. For example the total cost for the case one was 12,831.74 Euros (=116,000 SEK / 9.1665 SEK/EUR + 176.96 EUR). Since the contract was not exercised, the amount needed is obtained from the spot market at the rate at time T. Since the contracts will not be exercised in the cases 1b or 2b either, the total costs are the spot price for the full amount but with only half of the premium. Table 3.7 presents the total costs for all option hedging cases,

Table 3.7

Case	Contract Size in SEK	Exercise	Total Costs in Euros
1a	116,000	No	12,831.74
2a	88,000	No	9,557.68
3a	93,000	Yes	10,063.57
1b	58,000	No	12,743.26
2b	44,000	No	9,480.45
3b	46,500	Yes	10,094.39

In the cases 3a and 3b, the contract is exercised. The total cost is obtained with the following way, 93,000 SEK / 9.3200 SEK/EUR + 85.03 EUR = 10,063.57 Euros. And for the 3b,

(46,500 SEK / 9.3200 SEK/EUR) + (46,500 SEK / 9.1850 SEK/EUR) + 42.52 EUR = 10,094.39 Euros.

When total costs of forward and option contracts are compared to each other, it can be seen how option contracts have a premium included. The writer of an option contract naturally requires a higher compensation since he is carrying the risk of uncertainty. Table 3.8 summarizes the total costs from forward and option contracts,

Table 3.8

Case	Spot	Forward	Option
1a	12,654.78	12,909.54	12,831.74
2a	9,403.22	9,644.58	9,557.68
3a	10,125.20	9,993.23	10,063.57
1b	12,654.78	12,782.16	12,743.26
2b	9,403.22	9,523.90	9,480.45
3b	10,125.20	10,059.22	10,094.39

The locked-in rate is unfavorable for forward contracts 1a and 2a and on limited basis at cases 1b and 2b. The costs for the same option situations are the spot price and the added premium. On the case three, the option contract was exercised and our corporation benefited from it. In these cases, the forward hedging is the most efficient one and as noted above, this is due to an option premium. Seems that the 50 % option strategy offers a great amount of flexibility while the costs are cut in half (compared to full hedging).

4. Conclusion

In our example case, a medium sized corporation is exposed to a currency rate risk since it purchases a significant amount of goods in Swedish krona while the home currency and sales are in Euros. Three different cases were analyzed with two different ways of hedging. Although the case amounts of currency were quite low, they represent the real transactions of our company and therefore give the best image of exposure. Also, the total amount of purchases from Sweden is estimated to be around 700,000 Euros per year. This sum is divided into many smaller transactions like our three examples. If we decided to include the whole exposure (the all transactions in foreign currency) it would require more sophisticated measures and tools. The goal in this paper was to study what kind of exposure the corporation faces and what can be done to hedge from it.

What comes to the currency rates, it is essential for our corporation (and also for all other companies in the EMU area who participate in international trade) to understand how European Central Bank (ECB) controls the EURIBOR rate and therefore indirectly the valuation of Euro. And even better, to learn how to estimate the current trends in the yield curve and to make profound financial decisions based on facts. If we can anticipate the changes in economical activity in the EMU area, we can estimate if Euro is going to devaluate or revaluate against foreign currencies. Obviously, the better the estimations of the future trend, the more effective our hedging is. However, keeping in mind that Sweden has a right-wing government in power instead of the Social-Democrats, it could be a possibility (in some distant time period) that Sweden joins the European Monetary Union and introduces the Euro currency to Sweden. This would obviously remove the uncertainty in our company's purchases.

There are many opinions if hedging will increase the company value. Some suggest that hedging does not increase the company value in listed companies but could do so in private companies like in our case corporation. The argument sounds reasonable since in a private company, not all information is widely available and a constant monitoring of currency conversion costs should give a professional image of how the company is run and increase its possible future cash flows which can be used as a basis of a company valuation. In other words, it can be that the investors assume that a hedging from an unnecessary currency risks is essential every day action in a listed company instead of something extra which will increase the company value.

The forward hedging was straightforward. The currency rate was locked in with the forward rate (on the day of purchase decision) and the amount of currency was therefore fixed to a certain level. The market movements were not favorable for our two first cases. The Swedish krona devaluated during the maturity, thus it would have been more beneficiary to purchase the amount needed from the spot market. Naturally we would have had an open position for the currency risk which has to be taken into consideration but the spot rate is still more favorable to our corporation when situations are back-tested. The Swedish krona revalued during our third case and some profit was made. It was noted how 50 % strategy smoothened the surprisingly active market movements. The strategy cut our profits but also our losses and would suit our corporation's needs nicely. Due to its simplicity, a forward hedging seems appealing to our corporation at the moment.

The second part consisted of option hedging. While a little more complex and costly, it offers a great way to benefit from favorable market movements and still to maintain an option not to exercise the contract. The main disadvantage over forward/future contract is the premium which can be high sometimes.

The most significant factor in Black-Scholes option pricing model is the estimation of volatility. Usually, an implied volatility is used which is derived from the same equation with the market price of call option. In other words, a market estimated, or implied, volatility is used as a basis for estimating the price of a call option with a different maturity. In this paper, a historical time series based approach was chosen. The volatility was estimated 30 days before the contract begins to get the most recent volatility of the currency rate. The main idea with 30-day volatility was the possibility that the historical volatility beyond this time period does not correlate strongly with the near future volatility.

For our corporation, we came to the same conclusion than with the forward contracts, the 50 % strategy cut our premiums effectively in the half while the difference in the total amount paid was not too extreme. Again, the 50 % strategy helped to reduce the hedging costs to a minimum. Thus, 50 % strategy is favored over a full hedge strategy in options contracts. Since our corporation has not performed this kind of hedging before and the Chief Executive Officer and Chief Financial Officer (CEO and CFO) might lack some skills in the area of currency derivatives, it might be advisable to start hedging with 50 % of our purchases with forwards. Special attention should be paid on possible pooling of purchases to create more effective transactions. This should be possible since the amount of purchases is quite stable around 700,000 Euros per year. The 50 % hedging strategy would enable our corporation to benefit from some of the market movement while being hedged to half of it. And when the hedging skills increase, our corporation should start looking into options as a future possibility.

In the future, it would be interesting to study how effective a pooled purchase 50 % strategy with forwards or options could turn out to be. If the payoff was only one percentage of the total purchases, our corporation would make instantly 7,000 Euros in a year. A successful hedging strategy would then increase earnings per product sold later on and give our company more edge on the market of tight competition.

5. References

I. Bjønnes, G.H. Rime, D. Solheim, H.O.A. (2003). “Volume and Volatility in the FX Markets: Does it Matter Who You Are?”. *Working Papers, Norges Bank*. August 20.

II. Black, F. and Scholes, M. (1973). “The Pricing of Options and Corporate Liabilities”. *Journal of Political Economy, 81*. 637 - 654.

III. Børsum, Ø. G. (2005). “Currency Hedging in Norwegian Non-financial Firms”. *Norges Bank, Economic Bulletin, October 2005; 76, 3*. 133.

IV. Copeland, L. (2005). “Exchange Rates and International Finance”. *Prentice-Hall*. 4th Edition. 282 – 307.

V. Cox, J.C. Ross, S.A. & Rubinstein, M. (1979). “Options Pricing: a Simplified Approach”. *Journal of Financial Economics, 7*. 229 - 263.

VI. Fabozzi, F.J. Modigliani, F. Jones, F.J. Ferri, M.G. (2002). “Foundations of Financial Markets and Institutions”. *Pearson Education International*. 3rd Edition. 496 – 626.

VII. Garman, M.B. & Kohlhagen, S.W. (1983). ”Foreign Currency Option Values”. *Journal of International Money and Finance*, 2(3), 231 – 237.

VIII. Hull, J.C. (2005). “Options, Futures and Other Derivatives”. *Prentice-Hall*. 6th Edition. 1 -15, 21 – 40, 47 – 67, 75 – 93, 129 – 143, 181 – 198, 281 – 301, 313 – 333, 611 - 632**.**

IX. Loderer, C, and Pichler, K. (2000). “Firms, Do You Know Your Currency Risk Exposure? Survey Results”. *Journal of Empirical Finance*. 7: 317 – 344.

X. McDonald, R.L. (2006). “Derivatives Markets”. *Pearson Education*. 2nd Edition. 1 – 11, 21 – 47, 91 – 113, 127 – 160, 279 – 304, 375 – 404, 585 – 609, 679 – 697.

XI. Shapiro, A.C. (1991). “Foundations of Multinational Financial Management”. *Boston (MA). Allyn and Bacon*. 110 – 131.