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MARKET RISK HEDGING UNDER LIQUIDITY CONSTRAINTS

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INTRODUCTION

Following the Financial Crisis that began in 2007, liquidity risk became a centre of interest in financial research, though several notable events of the twentieth century had already proved that inadequate management of liquidity can be a source of serious problems.

In December 1993, a banking consortium saved the German giant company Metallgesellschaft (MG) AG from bankruptcy, as its U.S. subsidiary MG Refining and Marketing reported a $ 1.3 billion loss on derivatives transactions. In September 1998, Long-Term Capital Management (LTCM), one of the most successful hedge fund monsters of the previous years, accumulated a loss of $ 4.6 billion on "arbitrage" transactions.

In both stories the financial difficulties caused by unrealised mark-to-market loss of financial derivatives and hedged positions led to the cut of MG’s hedging program and even, in the case of LTCM, to the liquidation of the fund. Both events shocked the financial world, as experts neither inside nor outside those companies envisaged such serious consequences. It cannot be supposed that any of these companies would lack the tools or financial expertise to calculate the risk of the positions, as one of the owners of MG was the largest financial institution of the world, Deutsche Bank, and LTCM was created and led by the stars of Wall Street and two Nobel Laureates in the field.

A similar, but essentially smaller example of the Hungarian market that we can mention is the financial losses of Hungarian exporting companies in 2003 and in the post-crisis period of 2008-2009, which caused many of them financial distress.

In spite of the above examples, only after the financial crisis of 2007 did it become clear that the unlimited financial liquidity assumed in financial theory does not hold in reality. Financial markets dried up as a consequence of the crisis, making not only small investors and enterprises face financial constraints, but also the central participants, the financial institutions.

The rapid development in the global economy and better availability of financial markets have caused economic risks to become increasingly complex in recent decades. The management of financial risks is of primary importance, but as the above examples illustrated, although in theory hedging of market risk through financial derivatives decreases corporate exposure, liquidity risk deriving from the financing need of the derivative position can even lead a corporation to bankruptcy.

Risk management refers to a much wider range of tasks than hedging of certain types of risks, but in this thesis I examine exclusively the management of market risk, taking into account its consequences on the financing possibilities and liquidity of the company. The corporate strategy and the investment decisions are considered to be given. The company is presumed to not have any comparative advantage, either information or position, that would make it value enhancing to assume the risk.

The aim of this research is, on the one hand, to model and integrate the funding liquidity into models of corporate hedging theory; and on the other hand to compare the results of the theoretical model with the practice of corporate risk management that will be analysed in empirical research. The focus is to find and model the factors influencing the financial risk management in theory and practice and to analyse the effect of the financing need of the hedge position on the optimal hedging strategy, the hedging instruments, and the hedge ratio.

The answers to these questions are important not only from a theoretical perspective, but they can assist corporate decision making and even assist financial institutions in corporate analysis and product development.

Furthermore, the topic has relevance for regulators; better understanding of the process and motivation of corporate risk management is of macroeconomic importance and supports the decision-making of the regulating authorities.

The dissertation includes two parts: the first contains the results of the literature, and the second part describes the own research.

The first chapter presents some case studies: the famed financial falls related to market risk management, which motivated the research.

The second chapter gives an overview of the concepts of risk and risk management, and it analyses the relevance of individual and corporate risk management. The value of risk management can be derived from the individual utility function, while the corporate risk management is to be explained by market imperfectness and management incentives. As the funding liquidity - the availability of financing – is in the centre of the dissertation, the theories focusing on financial constraints are reviewed in details. Although utility function is interpreted for individuals, the corporate utility function is used to incorporate the explicit and implicit costs of financial distresses.

The theories incorporating the financial need of hedging are introduced in the third chapter. These models determine the optimal hedging ratio by comparing the increased utility of the volatility reduction with the costs of financing or with the risk of the position liquidation.

The second part of the thesis contains the own results.

In the fourth chapter I examine the optimal hedging in an own model, based on the results of the literature. This model releases often used assumption of zero expected value of the hedging position. So the hedging affects not only the variance of the profit and through the financing costs its extent, but the expected value of the hedge has an impact also. Furthermore, I analyse the effect of non-static financing costs, when the credit spread changes in the function of the financing need as well.

In the fifth chapter the analysis is developed in a multistage simulation model, where the hedge position needs to be financed several time during its lifetime, on the other hand the hedging position itself is concluded for more maturities. The optimal hedging ratio based on the expected utility of different hedging strategies is analysed. The funding risk appears in the model not only as the potential cost of the credit spread, but explicit financial constraints of the financing are built in also. The risk factor is the fluctuation of the euro exchange rate against the Hungarian forint, which is simulated in a GARCH(1,1) model.

The sixth chapter presents the empirical research. The research questions are based on some empirical facts and on the results of the model. The data used to the analysis are provided by the Hungarian National Bank and a Hungarian commercial bank.

The financial derivatives used to hedge interest rate and currency risk are typically traded in over the counter (OTC) markets. Although according to the new European regulation, being introduced in the year of submitting the thesis, trading partners have reporting obligation in case of OTC derivatives, the available data about that kind of deals is limited.

The aim of the thesis is to describe the Hungarian corporate risk management as precisely as possible.

I. PART: LITERATURE REVIEW

1 FAMOUS FINANCIAL LOSSES CAUSED BY HEDGING POSITIONS

The difficulty of answering financial questions derives mainly from the uncertainties concerning the future. Without risks, the main issues of investment and corporate finance like asset and company valuation would only be simple discounting tasks and the effects of incentives and asymmetric information would not be relevant (Merton, 2008). The management of risks is one of the main tasks of corporate management not only in the theory but also in practice. It is a more and more common opinion (Merton, 2008) that despite the classical approach, according to which the significance of risk management means protection against the worst consequences, risk management also generates value by providing protection against the risks in the taking of which the company does not possess comparative advantages, and therefore, its risk-taking possibilities are extended in the areas of strategic importance.

Stulz (1996) emphasises also that risk management shall not necessarily aim to minimise variance, but it is worth to take risks in those areas where the company has comparative advantages, by ensuring the downside outcomes of significant costs at the required level.

According to Lessard (2008), the “hierarchy theory” of corporate risk management is as follows: the first and most important is to define those activities which the company has comparative advantages in, and risks shall be taken here. The first level of risk management is related to the operation of the company; business strategy and operative management are defined along this. The management of financial risks means the management of the risks arising / remaining as a result of the real decisions.

Contrary to this, Hommel (2003) considers operating flexibility as an alternative of financial risk management, indicating the conditions under which it is worth to apply operative hedging instead of financial risk management at the company.

As the negative effects arising from the excessive risk exposure may have serious social consequences, various regulations and recommendations were prepared for managing and mitigating the extent of the risks taken by the different economic participants[1]. The rate of risk taking of banks, due to their special role in economy, was already regulated at the end of the last century. The 1988 recommendation of the *Basel Committee on Banking Supervision,* an international banking supervision organisation operating as an independent entity under the aegis of BIS (Bank for International Settlements), which soon was incorporated into the regulations of the different countries, limited the financing leverage of the banks by introducing a minimal capital adequacy ratio. The rules known under the name 'Basel II' were prepared in 1999 (BIS, 2004) which specified the assessment of the market and operating risks, as well as the holding of the related capital. The directives of Basel III (BIS, 2011) are currently being implemented; they aim to limit two other types of risk as well, the liquidity- and the system-risk.

Berlinger et al. (2012) emphasize the necessity of the *global regulation of risk taking* (risk maximising), as the limitation of leverage at certain economic operators does not ensure keeping the risks below the required level globally.

The limitation of the companies' leverage is not present in the regulations. The integrated approach of the management of corporate risks is summarised in the "*Enterprise Risk Management* (ERM)" concept of the Casualty Actuarial Society (2003), which provides guidelines to the systematic and complex management of the risks affecting the companies. According to this concept, similarly to the views highlighted by Stulz (1996) and Lessard (2008), the main task of corporate risk management is not to minimise risks, but to optimise them and to align them with the company's risk appetite. It classifies the risks into 3 main categories: strategic, operational and financial risks[2], and further divides financial risks into market, liquidity and credit (partner) risks. Financial risks can be hedged by natural hedge, by derivative financial products, diversification and by purchasing insurance. The method of hedging is mainly determined by the type of risk (whether the product is traded on the market, what kind of hedge instruments are available). From among the market risks, exposure to the FX exchange rate affects those companies the receivables and liabilities of

[1] Annex I. provides an overview concerning the regulations and recommendations effective in different markets.

[2] The quoted source also mentions a 4th category, "hazard risk", but this can also be considered as part of the operational risk.

which are denominated in different currencies. The fluctuation of the interest rate affects particularly the company's financial profit (this is illustrated by the corporate growth model of János Száz (2007)), but it is also present in the management of the FX exchange rate risk by interest rate parity. Typically, only a narrow segment of the companies has exposure against commodities as market risks.

The following sections present one of the motivations of this thesis, the significant company losses related to derivative transactions, and the summary of the lessons drawn from these.

1.1 The story of Metallgesellschaft

The remarkable financial scandal of the 90's, the Metallgesellschaft story mentioned in the introduction has been a subject of several academical analyses[3] since then. Although in the years of the crisis, a number of companies[4] suffered losses exceeding ten billions of dollars on their derivative transactions; a loss of one billion dollars broke records at the end of the twentieth century. This case has become one of the favourite examples of textbooks as it provides realistic frameworks to the presentation of a variety of financial risks and to the analysis of the links of among them.

MG Refining & Marketing Inc. (MGRM), the US subsidiary of the 14th largest German company, Metallgesellschaft AG launched a powerful marketing programme in the early 90's and offered petroleum contracts for the long term with different facilities, within the frameworks of which they undertook to supply the agreed monthly quantity at fixed rates for 5 and 10 years in advance. By 1993, the contracted quantity reached some 154 million barrels. The contracts also contained different options for termination which further complicated the pricing of the transactions and the management of the risks, but these are not significant in terms of presenting the basic problem. As MGRM only possessed a part of the capacity over the contracted products (it had a share in and a long-term contract with Castle Energy refinery), it hedged its commodity risk by futures[5] and over-the-counter

[3] The sources used here: Culp and Miller (1995), and Mello and Parsons (1995).
[4] The American AIG insurance company reported a loss of USD 62 billion in Q4 2008, and by this, its annual loss reached USD 99 billion.
[5] Annex II. contains a summary of financial derivative products.

(OTC) forwards and swap transactions. For the reason that the market of contracts with terms exceeding 18 months is rather illiquid, the company decided to hedge its exposure with short-term (1 month) contracts for the quantity equalling its supply obligation, and rolled the stack from month to month, decreasing it by the delivered or closed quantity.

MGRM's business strategy was to take over the commodity risk of its clients and to hedge it more favourably due to its market power and market knowledge, i.e. to exploit its comparative advantages in this area. Considering it this way, the strategy and the risk management comply with the corporate goal of maximising corporate value mentioned by the ERM concept, as well as by Stulz (1996) and Lessard (2008). On the other hand, Mello and Parsons (1995) draw the attention to the fact that the basic strategy itself was wrong; the positive results in the business strategy only derived from the profit generated by the speculations for the petroleum derivatives.

Without judging the strategy, let's examine the risks posed by MGRM's hedging[6] strategy, due to the losses of which the parent company decided to stop the programme. The risk arising from the operation (sale of long-term petroleum derivatives at fixed prices) is a market risk, the company's operative profit or loss is the difference between the fixed price (K) and the current spot petroleum price (S_t, the date is indicated by the index) for each expiry. By futures contracts, the risk of the price changes can be hedged perfectly, provided that a product which moves perfectly together with the basic exposure exists on the market, in this case, a futures contract expiring exactly at the date of the delivery. However, partially deliberately and partially due to the market conditions, the company did not choose this hedging strategy, but hedged its total exposure by short-term futures purchases rolled from one month to another. As a consequence, it took another risk, i.e. the risk of re-concluding, which in this case means the basis risk deriving from the difference of the futures and spot rates. The definition of the basis[7]:

$$b = F - S \tag{1}$$

[6] Mello and Parsons (1995) argue that due to the inherent speculative element, this strategy cannot be considered as a hedge strategy.

[7] Hull (1999) uses an alternative definition: Basis = spot price of the product to be hedged – future price of the hedge product

Where b stands for the basis, F is the futures price of the hedging product, S is the spot price of the product to be hedged.

The basis derives on one hand from the difference of the underlying and the hedging product, and on the other hand, from the difference of the spot and future prices. Supposing that there is a derivative for the basic product and it can be traded, the previous component is zero; the basis equals the difference between the future price and the spot price. In the case of products which do not generate any cash-flow during their tenor, the future price only differs from the spot price due to the time value caused by later payment.

In the case of commodities traded on the financial market, like oil, there are two more components of the difference: the convenience yield of physically holding the oil, and the costs of storage (Hull, 1999):

$$F_{t,T} = S_t + b_{t,T} = S_t e^{(r_{t,T} + u_t - y_t)*(T-t)} \tag{2}$$

Where:
t: current time
T: time of maturity
$F_{t,T}$: in T maturing Forward/Futures price in time t
S_t: spot rate in time t
$b_{t,T}$: basis in time t until time T
$r_{t,T}$: continuously compounded riskfree rate in time t maturing in time T
u_t: continuously compounded storage cost in time t
y_t: continuously compounded convenience yield in time t

If the company hedges for expiry, the profit of the main activity and the hedging (π) for each (t_n) expiry is the difference of the fixed price (K) and the spot price at expiry, and the value of the futures position – we do not consider the settlement of the value of the futures transaction during the tenor -, which, using Equation (1) is:

$$\pi_{t_n} = K - S_{t_n} + S_{t_n} - F_0 = K - (S_0 + b_0) \tag{3}$$

Consequently, the result is independent from the changes of the spot price and the basis during the tenor, uncertainty can be avoided completely by hedging. On the oil market, the basis is often negative (Culp and Miller, 1995), resulting from the fact that the convenience yield exceeds the cost of carry consisting of the storage and interest costs in several cases. This way, the futures price is lower than the spot price, and as the futures price converges to the spot price when expiry approaches, the company can realise a higher margin due to the futures hedging.

In case of hedging the position exposed to commodity risk by short-term long futures, the position is closed at expiry of the hedge transaction, and it has to be recontracted for another period. Consequently, the profit of the hedge transaction shall be settled – as I present it, in case of futures this happens on a daily basis without closing the position -, and on the other hand, although the company is protected against the changes of prices, the basis of the new hedge position may change.

Therefore, the profit on each expiries will be independent from the changes of the spot prices (not considering the time value of the settlement), but they depend on the changes of the basis.

$$\pi_t = K - S_t + \sum_{i=1}^{t}(S_i - F_{i-1}) * e^{r_i(t-i)} = K - S_t + \sum_{i=1}^{t}(S_i - S_{i-1} - b_{i-1}) * e^{r_i(t-i)} \quad (4)$$

Considering the risk-free interest rate to be zero, Equation (4) can be rewritten in the following form:

$$\pi_t = K - (S_0 + \Delta S_{0,t}) + \Delta S_{0,t} - \sum_{i=1}^{t} b_{i-1} = K - S_0 - \sum_{i=1}^{t} b_{i-1} \quad (5)$$

As in Equation (5) the change of the basis is yet unknown, the actual profit becomes stochastic, this is the basis risk affected by the changes of the interest rate.

The other risk, which is included in the strategy independently from the maturity mismatch, derives from the settlement rules of the futures contracts. The P/L of the futures position is settled on a daily basis during the tenor, causing significant cash-flow fluctuations to the hedging company[8]. Equation (4) shows the values of the different expiries as the sum of the

[8] Chapter 4 examines the liquidity consequences of OTC derivative transactions.

value of the oil sales of the given expiry and that of the transaction contracted for hedging them. However, at every expiry, the P/L of all living hedging contract will be settled. Examining a contract with a 10-year tenor specifying the delivery of a monthly unit quantity (1 million barrels) at a fixed price, supposing that the company hedged the whole quantity (120 million barrels) with a rolling stack strategy, the cash-flow of the different expiries is as follows:

$$CF_t = (K - S_t) + (120 - t) * [S_t - (S_{t-1} + b_{t-1})] = (K - S_t) + (120 - t) * (\Delta S_t - b_{t-1,t}) \quad (6)$$

Equation (6) shows that for the first expiries, besides the price change of the oil to be delivered, the mark-to-market value of a nearly 120-fold position is also settled, together with the change of the basis, that is compensated by the value change of the signed long-term contracts, however, they do not generate any cash-flow according to the agreement with the customers before the expiry. Due to this, Mello and Parsons (1995) explain that the company could have hedged its commodity risk optimally with a significantly lower hedge ratio, around 56%.

When deciding about the hedging strategy, as it is clear from MGRM's business plan, not only hedging the risk was aimed, but the company's management intentionally took the basis- and cash-flow risks in order to profitate from the mispricing of the market:

"However, it is important to recognize that if a hedge program is carefully designed to "lock in" a favorable basis between spot and futures prices at the most advantageous time, hedging can generate trading profits which can substantially enhance the operating margin. Our proposed risk management program, discussed below, not only protects the pump profit margins with a minimum amount of risk from the spot market, but also offers us an opportunity for extraordinary upside profit with no additional risk." Cited by Mello and Parsons (1995) from MGRM's business plan.

According to the management, the negative basis as a market inefficiency can be used and the company can take advantage in form of extra income. They supposed that similarly to the experiences of the previous years, the basis would remain negative with unchanging oil prices, and this way, with futures purchase, this difference could be gained continuously, ensuring continuous positive cash-flow to the company. According to the analysis of Mello and Parsons (1995), the profit of the business plan was exclusively based on the gaining of the basis[9].

However, in 1993, the market changes affected MGRM's positions negatively from two directions. On the one hand, the basis which had been negative for years changed to positive, and on the other hand, due to the unsuccessful quota agreement of OPEC, the oil prices started to decrease (see Figure 1).

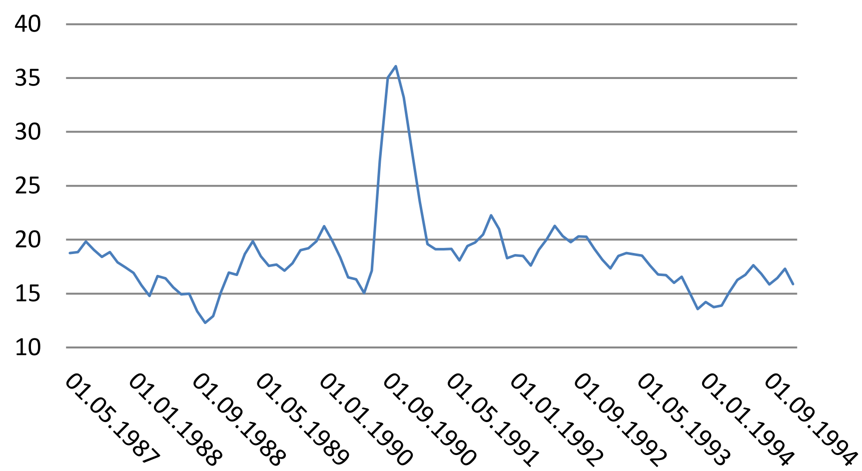


Figure 1: Crude Oil monthly prices between 1987 -1994

Source: http://www.indexmundi.com/commodities/?commodity=crude-oil-brent&months=300

As a result of the change in the basis, the profit decreased (see Equation (5)), but a more serious problem was caused by the settlement obligation of the loss of the futures transactions. MGMR has already drawn down its credit lines during the summer of 1993, and as a result of the further decreasing oil prices, it could hardly find any partners who would have been willing to enter into new transactions with it and to roll its hedging positions. By the end of 1993, the company reported a financial loss of USD 1.3 billion, and the parent company decided to close the whole programme. In order to cover MGRM's financial losses, MG AG had to apply for a credit package of USD 1.9 billion to the coverage of its other assets, and it had to implement serious cost-savings measures in other business lines as well.

[9] The strategy was much more complex; it also aimed to exploit the price consistency of the different products in addition to the inefficiency of the futures market. The activity of the company was mainly financial intermediation and commoditiy trading.

Regarding the decision of the parent bank, the opinions detailed in the literature are not uniform. Culp and Miller (1995) argue that the management made a wrong decision when it closed the long-term supply agreements which were clearly profitable, without requesting any compensation from the buyers. With this step, they realised the losses of the hedged position without keeping the profitable transactions. In their opinion, MGRM's problem was exclusively caused by the lack of liquidity, and it should have had borrowing capacity for hedging the derivative positions as the net present value of the whole position was positive. The loss of the derivative positions was exceeded by the positive value change of the basic position, and this could have provided sufficient collateral to further financing. Furthermore, the increasing oil prices would have generated adequate cash-flow in 1994 for the repayment of the credits taken to finance the position.

Mello and Parsons (1995) contest several parts of this argument; according to them it is not true that a unit change in the value of the short-term, derivative position causes the same change in the long-term underlying position; therefore, due to the 100% hedging ratio, MGRM did not only face a liquidity problem but also suffered real losses. They also emphasize that neither MGRM, nor the parent company was in the position to find a financing partner easily for maintaining the mainly speculative positions. The other problem, due to which the positive value of the long-term agreements shall be considered carefully, is the credit risk. This way the parent company's decision to close the programme can be understood. They also draw the attention that if the risk-taking regulation applicable to the banks were valid for MGRM as well, they could not have undertaken a position with such a high risk.

1.2 The fall of Long-Term Capital Management[10]

John Meriwether, former leader of Salamon Brothers' bond trading department and later vice-president of the company, established his own hedge fund[11] in 1993, which aimed to gain extraordinary yields from market mispricing and inefficiency. In addition to the most

[10] This story was written in several bestsellers, including Dunbar (2000), and Löwenstein (2007) through the detailed presentation of the participants and the motivations.

[11] A special, high-leverage investment fund which does not exist in Hungary; its capital is provided by large investors and creditors, therefore, it is subject to less supervisory requirements.

successful and most well-paid traders of the Wall Street, two Nobel Prize laureates (Robert Merton and Myron Scholes won the Nobel prize in 1997 in economic sciences for their results achieved in the area of derivative pricing) were also among the partners of Long-Term Capital Management. LTCM managed the assets of Long-Term Capital Portfolio LP, a fund registered on the Cayman Islands.

LTCM started its operation in February 1994, with an initial capital of USD 1 billion. Its strategy was to exploit the arbitrage opportunities[12] of the market by using the most developed mathematical-financial tools. Their main trading strategy like bond arbitrage was to utilise those market conditions where the prices of two very similar investment opportunities (e.g. a 30-year and a 29.5-year USA government bond) differed to a higher extent than justified by the expiry difference. As during the tenor, the prices of the two products necessarily converge, profit can be achieved by exploiting the pricing inconsistency (purchasing the relatively cheaper product and selling relatively more expensive).

In 1994, the nearly one-year yield of the fund was 20%, in 1995 it was 43%, in 1996 41%, and in 1997 the yield was 17%, significantly exceeding the expectations of the investors.

Such arbitrage opportunities are sought by all market participants, therefore, extremely large volume transactions or high leverage is needed for utilising them. By the summer of 1998, LTCM's capital accounted for USD 5 billion, the value of its assets reached 100 billion, and the nominal value of its derivative positions reached USD 1000 billion.

The immediate reason causing LTCM's problems was the Russian crisis of 1998. Although the company had a relatively moderate exposure in the Russian market, the effects of the crisis spread to the financial markets of the world, increasing volatility, the yields ran up, while the asset prices started to decrease. The strategies aiming to utilise the pricing inconsistencies generated losses, as it is noted by Dunbar (2000), the fact that the prices of certain assets shall be equal in the future does not mean that in the short term, the difference cannot increase further. As the long positions of LTCM consisted of illiquid, therefore cheaper assets, their prices sank even deeper during the crisis, and the maintenance of the positions required more and more capital from the fund. In the second half of September 1998, the pre-crisis capital decreased by 70%, to 1.5 billion. The losses were increased by

[12] Arbitrage: with zero initial investment, certainly no loss, but gain with positive probability can be achieved

the fact that due to the market changes, the risk measures (VaR values[13]) skyrocketed and the risk monitoring systems supervising the levels of such measures warned the company to decrease its exposures, which caused further decrease in the market prices and realising losses. LTCM’s losses exceeded USD 4.5 billion between January and September 1998 (Löwenstein, 2007).

As LTCM was a key player of the market and its fall would have caused the financial markets to collapse, a banking consortium established by the coordination of the central bank of the United States, FED[14] provided a bailout of USD 3.65 billion in order to liquidate the fund’s positions, and the participating banks got 90% share in the fund.

Furthermore in order to maintain the liquidity of the markets, FED decreased the interest rates several times. The fund’s positions were closed by the beginning of 2000 and they also repaid the bank credits with a slight profit. However, the original investors of the fund practically lost all of their investment.

1.3 The Hungarian exporting companies

The price changes of the first half of 2003 caused significant financial losses to several Hungarian exporting companies, which seemed to be surprising, because in theory, the weakening exchange rate is favourable for exporters. The losses were caused mainly by transactions concluded for hedging the exchange rate risks, and as in the previous years, the financial reports contained profit, the losses seemed to be even higher.

Although the largest financial difficulties were suffered by non-listed companies, due to the easier access to these figures, Table 1 presents the semi-annual reports of 2003 of some exporting companies listed on the Hungarian stock exchange.

[13] See the detailed explanation of Value at Risk as a risk measure in Chapter 5.
[14] Federal Reserve System

	Revenue MFt	Operating P/L MHUF	Operating margin MHUF	Financial P/L		P/L on currency trading	
				MHUF	% of the revenue	MHUF	% of the revenue
Richter	54,918	15,134	27.60%	877	1.60%	-1,014	-2%
Egis	42,544	4,983	11.70%	164	0.40%	-1,836	-4%
Rába	14,568	-2,744	-18.80%	-938	-6.40%	-715	-5%
Bchem	67,800	7,608	11.20%	-4,292	-6.30%	-3,538	-5%

Table 1: Semi-annual P/L of public Hungarian exporting companies reported in 2003
Source: BÉT semi-annual financial statements

The losses were a consequence of the exchange rate risk management practice of the previous years. Following the foreign exchange liberalisation in 2001, the HUF exchange rate strengthened against EUR almost continuously, while the Hungarian yield levels exceeded the interbank market EUR yields by 3-5 percentage points[15]. The forward premium (basis) deriving from the interest difference, contrary to the commodity market indicated in the MG story, in terms of EUR/HUF[16] provided extra profit to the EUR sellers in the case of unchanged spot prices. Consequently, mainly the Hungarian exporting companies hedged their FX positions exposed to exchange rate risk, and they concluded as long deals, as allowed by the bank limits. In January 2003, due to a strong HUF demand from abroad, the HUF exchange rate reached the value of 234.69, the lowest level of the effective intervention band. However, due to the HUF sales of the Hungarian National Bank satisfying all demands, the Hungarian currency weakened 4% in one day, and by the end of June 2003, the EUR/HUF exchange rate increased by another 9%[17].

[15] Annex III. shows the exchange rate and interest rate changes of the period.
[16] Based on the financial market convention, when indicating the currency pairs, the base currency is the first one.
[17] The reasons of the speculative attack against the band and the management of this are presented by the 2003/3 study of the Hungarian National Bank.

The value of the long forward FX position before expiry is the net present value of the sum of the spot exchange rate change and the change of the basis:

$$sf_{t,T} = Ke^{-r_{t,T}(T-t)} - S_t e^{-q_{t,T}(T-t)} = -(\Delta S_t + \Delta b_t)e^{-r_{t,T}(T-t)} \quad (7)$$

Where:
t: current time
T: time of maturity
$sf_{t,T}$: value of the short forward position maturing in time T, in time t
S_t: spot rate in time t
K: initial forward rate
$r_{t,T}$: continuously compounded domestic (HUF) riskfree interest rate in time t, maturing in time T
$q_{t,T}$: continuously compounded foreign (EUR) riskfree interest rate in time t, maturing in time T
Δb_t: change of the basis until time t
ΔS_t: change of the spot price until time t

The unrealised value of the hedge (long forward) position was affected negatively not only by the change in the exchange rate but also by the increase of the HUF yields. For the expiring hedge transactions this meant that the actual exchange rate was less favourable than the spot rate, but as the forward rate was known in advance, it did not affect the company negatively. The exchange rate losses of the expiring transactions were offset by the profit (compared to the forward price) in the operating profit.

However, losses did not only appear on the expiring derivative transactions, but the whole open position was revaluated, as a result the value of all open forward transactions according to Equation (7) was included in the financial profit or loss. The longer expiries and the higher notional the firm hedged, it had to account the more significant unrealised losses. For example, if in the beginning of 2003, the company hedged its revenues for 18 months in advance at a monthly basis, due to the exchange rate changes in the first half of the year, it suffered a financial loss of 10-15% of its annual revenues in the middle of 2003, which, based on the figures of Table 1, exceeds the total operating profit in the case of several companies.

As a consequence of the global financial crisis, a similarly extreme exchange rate movement occurred on the Hungarian financial markets in the second half of 2009.

However, the notable losses were not only caused by the hedge positions, but rather by the speculative open foreign exchange positions concluded for exploiting the interest rate differences.[18]

1.4 Lessons of financing difficulties of derivative positions

In each of the three presented cases, the financial losses of hedging derivative positions, - which aims to decrease the market risks - caused financing difficulties which were critical in terms of the company's survival. Although the future convergence of the prices of the exposure and the hedging derivative ensures value compliance and a minimal variance at the expiry, but during the lifetime of the deal, permanent and significant differences may arise, causing considerable fluctuations in the cash-flow. Despite the classical theory of the textbooks, it is not always possible to obtain financing, even for a huge market player like Long Term Capital Management was in 1998[19]. Due to the lack of unlimited liquidity, the company shall be prepared for the financing of high leverage positions like derivatives.

It shall also be mentioned in relation to the aforementioned cases that as a result of certain market "anomalies" and favourable price changes which could have been utilised by the company, the undertaken positions and the size of the liquidity risk were supposed to be higher than in the case if risk management only aimed to minimise variance. The prices in the market, which, in the absence of financing constraints, contain arbitrage opportunities, include most probably liquidity risk priced in, and therefore, the strategy aiming to exploit these pricing mismatches requires the company to take serious liquidity risk.

Taking too large positions poses further risk, as the concentration of the market positions means that a partner for the quick closing of large positions is to be hard to find. As it was seen in the case of LTCM, a moral risk is caused by the fact that the other players of the market – in order to maximise their profits – drives the market against the large market player in trouble.

Corporate financial risk management – either if it aims to minimise variance, or to optimise risks and utilise comparative advantages – is closely connected to the financing of the

[18] The analysis of such derivative structure is in Boros and Dömötör, 2011.

[19] As it is mentioned by Péter Medvegyev (2010), the casinos do not prohibit the theoretically winner doubling strategy for decreasing their losses, but in order to protect their customers.

company (see the details in Chapter 2). Stulz (2008) draws the attention to the fact that risk management may not only be limited to observing the specified risk limits, stress tests shall also be performed in order to allow the decision-makers to assess the survival options of the company in worst-case scenarios.

2 RISK IN FINANCIAL THEORY

Uncertainty in economic decisions got into the focus of economic theory in the twentieth century. Knight (1921) was the first to distinguish explicitly uncertainty and risk, in case of risk the possible outcomes and their probability – so the probability distribution[20] – is known, while in the absence of those information we are talking about uncertainty (Bélyácz, 2010). As a consequence of the above definition, risk can be quantified, so mathematical-statistical tools can be applied to measure it[21]. The aim of the risk management is to optimally modify the distribution of the outcomes.

2.1 Individual risk attitude

When investigating the individual decision making under risk/uncertainty[22], Bernoulli (1738) formulated the *expected utility hypothesis*, according to which the individual preferences when choosing among risky outcomes (assets), is determined by the maximization of expected utility based on the individual utility function.

The main assumption of economic theory is the rationality of the decision makers, that was defined by Von Neumann and Morgenstern as the individual decision is (VNM-) rational if and only if there exists a real-valued function (*u*) defined by the possible outcomes such that every preference of the agent is characterized by maximizing the expected value of *u*[23] (Von Neumann and Morgenstern, 1947).

A rational investor prefers investment *X* against *Y*, if its expected utility is higher:

$$X \succ Y \qquad \Leftrightarrow \qquad E[u(X)] > E[u(Y)] \tag{8}$$

[20] Risk, uncertainty and probablility and their appearance in the economic theory are the topics of the inaugural study of Iván Bélyácz (Bélyácz, 2011)
[21] Risk measures are presented in subchapter 5.3.
[22] The literature of individual decision making is covered by Zoltayné (2005).
[23] Annex IV. contains the conditions of the existence of this function.

In case of more possible outcomes the expected utility is the probability (p) weighted average of the utility of the outcomes:

$$E[u(p_1X_1 + ... + p_nX_n)] = p_1u(X_1) + ... + p_nu(X_n) \tag{9}$$

Therefore the knowledge of the individual utility function is necessary to make an optimal decision, when choosing among risky outcomes.

A description of the *risk attitude of individual investors* and the formalization of their choices among risky investment possibilities first appeared in the works of Arrow (1970) and Pratt (1964).

The utility function (u) – ordering the level of individual utility to the wealth – is a twice continuously differentiatable function that is monotonically increasing (its first derivative is positive) meaning in case of wealth there is no satiation point, above which the marginal utility of a further unit becomes negative.

The individual risk attitude depends on the shape, the second derivative of the function. A risk neutral investor has a linear utility function; the utility function of a risk-loving investor is convex, while a risk averse investor has a concave utility function. In other words, the risk attitude of an individual investor is shown by the expected risk premium (π), the amount at which the expected value of the future risky inflow (z) has to exceed the certain future income that the investor is indifferent between them (Pratt, 1964).

$$u(x + E(z) - \pi(x,z) = E[u(x + z)] \tag{10}$$

The *risk neutral* investor requires a π of zero, the value of the risk premium is positive (negative) in case of risk averse (risk-loving) investors. According to the practice individual investors are risk averse, as an excess unit in the wealth has a lower marginal utility than the utility reduction suffered by losing the same amount, so the individual utility function is concave.

Consequently the „*fair*" game –more outcomes with a zero expected value – is refused by a risk averse investor. The popularity of the lotteries offering even less favourable conditions, than fair games can be explained by two reasons. Friedman and Savage (1948) argue that utility function is not totally concave, so the individual risk attitude can be different against different type of risks (small loss with high probability or huge loss with low probability). According to the other explanation the subjective probability realized by the individual can differ from the real probability priced in the game, so one can judge the unfavourable game to be advantages for him (Arrow, 1970).

Summing up, the risk averse investor's utility function $u(x)$ has the following properties:

$$u'(x) > 0 \tag{11}$$

$$u''(x) < 0 \tag{12}$$

Equation (11) refers to the non-satiation, while Equation (12) means the risk aversion. The value of the utility function itself is insignificant, only the preference it results is important. That is why utility function has to be invariant to positive affine transformations, so adding a constant or multiplying the function with a positive constant has to give the same utility preferences.

The extent of the individual risk aversion is defined by Arrow (1970) and Pratt (1964) with the following measures:

$$R_A(x) = -\frac{u''(x)}{u'(x)} \tag{13}$$

$$R_C(x) = -x\frac{u''(x)}{u'(x)} \tag{14}$$

The risk aversion is measured by the quotient of the second and first derivative of the utility function, as this ratio remains unchanged after a positive affine transformation of the function.

Both above functions show the risk aversion in the function of the wealth, in case of risk averse investor both measures are positive. Equation (13) is the measure of absolute risk aversion (ARA), Equation (14) shows the relative risk aversion (RRA). The former is the willingness to undertake a fix amount of gain/loss, the later quantifies the risk attitude when risking a given proportion of the wealth.

In practice constant absolute risk aversion (CARA) would mean the investor would risk – hold in risky assets - always the same amount, independently from the level of his wealth (Norstad, 1999). According to the empirical facts the individual investor is willing to risk a higher absolute amount, as his wealth increases, so his risk attitude shows decreasing absolute risk aversion (DARA).

The relative risk aversion is rather increasing (IRRA) in the practice (Arrow, 1970), but most of the utility functions in the theoretical models contain constant relative risk aversion (as the models of the next chapter). The most often used function is the iso-elastic utility function with the following general form:

$$u(x) = \frac{x^{1-\gamma} - 1}{1-\gamma} \tag{15}$$

Where γ, the measure of risk aversion, is above zero and it is the same, as the R_A ratio of Equation (13). In the special case of γ=1, the utility function is the logarithm function suggested by Bernoulli:

$$u(x) = \ln(x) \tag{16}$$

Individuals with constant relative risk aversion have decreasing absolute risk aversion; the reverse of the statement is not necessarily true.

Risk management – like every economic decision – is optimal if it maximizes expected utility. Hedging of financial risk means acquiring tools and positions that protect against variance in value (Connor, 2008), so hedging decreases the variability of the possible outcomes. *Hedge ratio* refers – through the whole thesis – to the ratio of the hedging position and the position exposed to risk. Under perfect hedge I mean the equality of the hedge position and the exposure[24], consequently in case of partial hedge the exposure exceeds the hedge position.

The shape of the individual utility function determines the effect of the risk reduction on the individual utility: deriving from the Jensen inequality, risk reduction increases the expected utility if the utility function is concave, so the individual is risk averse.

The risk attitude can change over time, but individuals are typically risk averse, so the costfree hedging creates value form them.

The irrational motives of decision are covered in the next chapter, but the thesis assumes basically rational decision-makers.

2.2 Relevance of corporate risk management

The economic concept of the utility function refers to individuals; it is not interpreted on the corporate level. On the other hand, if the manager itself owns the firm, the aim of the corporate decision making is to maximize the utility of the manager-owner, so the corporate behaviour is the same as the individual.

In case of the most often investigated corporations, the public limited companies, ownership and the management are separated, the share in the company is only an investment, part of the portfolio of the owner. Therefore aim of the corporate management is to maximize the shareholders' value, so corporate risk management creates value only if it enhances expected profit and thus also corporate value.

As corporate risk management affects the fluctuation of the cash-flow generated by the firm, the hedging modifies the financing and capital structure of the company. Miller and Modigliani (1958, 1963) proved that in a perfect market (no taxes, no transaction costs or information asymmetry), where all market participants have unlimited access to financing at the same price, changing the capital structure of the company in itself does not create value. It can be also shown that under the above assumptions hedging of financial risks (if

[24] The hedge ratio, used here, is not the same as in some textbooks (like Hull, 1999), which use it for the value change of the derivative assets as a function of the price change of the underlying product (delta).

the expected value of the hedging position is zero[25]), does not create value either, as the individual investor can hedge under the same conditions. Consequently, in this framework investors decide about hedging according to the utility function reflecting their own risk attitude, there is no need for a corporate level hedging. The share in the firm is an asset; it represents the wealth of the investor in the utility function. The different shareholders can decide about hedging according to their own risk appetite, and so corporate hedging would narrow the available risk spectrum.

In the real corporate practice, risk management is an important task of corporate management, which can be traced back to both *rational* and *irrational* reasons[26]. One direction of the theories describing corporate risk management models the value achieved by corporate hedging. These models explain the value of the hedge through the lack of the Miller-Modigliani assumptions, and the elements of the market imperfection – taxes, transaction costs, information asymmetry, and availability of financing – are analysed. Risk management practice can also be explained by analysing the incentives of the corporate management, but in that case hedging does not necessarily increase corporate value.

2.2.1 Value explanations for corporate hedging

Corporate value can be increased by hedging, insofar as it *reduces corporate tax burden*. Smith and Stulz (1985) demonstrate that in the presence of *convex* corporate *tax function*, the after-tax corporate profits that determine corporate value are the concave function of its pre-tax value. Hedging reduces the firm's expected tax burden; if the cost of hedging is smaller than the expected tax burden, firm value will increase.

Due to better access to financial markets, *transaction costs* relating to risk management at the corporate level are generally significantly smaller than the hedging costs of individual shareholders (Dufey and Srinivasulu, 1984). For this reason, corporate hedging contributes to maximization of shareholder value.

[25] This assumption will be released in my model
[26] A summary of the different risk management theories can be found in Hommel (2005), and also in the doctoral thesis of Flesch (2008).

Hedging can also increase firm value by resolving an *information asymmetry* situation between firm management and owners or between owners and creditors. Because firm management has more exact information about the firm's exposure to risk than shareholders do, it is more competent to make decisions regarding risk management (Stulz, 1984). A hedge plan that has been well pre-determined ensures that management will not decide on risk management according to its own risk preferences, and will also help the assessment of the firm management (these also appear in the following point).

Further theories explaining value creation by hedging are connected with the firm's *funding.* If the firm lacks internal funds, it must make use of an external funding source, which, in contrast with the Miller-Modigliani theorem, is expensive or not even possible at all. Funding-related costs can be either direct (administrative) costs or agency costs arising from *information asymmetry* (Myers, 1984, Tirole, 2006). Hedging decreases corporate cash flow dispersion, and as a result, the likelihood of financial distress is also decreased. The *costs of financial distress* also appear in the form of transaction costs, and higher expected bankruptcy costs decrease the firm's value (Smith and Stulz, 1985). Financial distress can result in a firm's partial or complete inability to effectuate its positive net present value investments, which also decreases firm value (Lessard, 1990, Froot et al, 2003). This paper deals fundamentally with the funding consequences of market risk management, so the following subsection describes in detail two theories tracing hedging to funding reasons- Froot, Scharfstein and Stein (1993), as well as Tirole's funding model of insufficient funding arising from the principal-agent problem.

A firm's goal is to maximize shareholder value, to which end firm management must take into consideration the aforementioned implicit costs entailing risk. Although the corporate utility function cannot be interpreted, it is for this reason that maximization of expected cash flow[27] decreased by costs associated with risk-taking is, as a corporate goal, equivalent to maximizing a risk-avoiding utility function (Bickel, 2006). Thus, it is a common assumption in models examining optimal hedging that a firm maximizes its (generally concave) utility function.

[27] Similarly, Stulz (1999) argues for consideration of the effect of diversifiable risks on corporate value.

2.2.2 Incentive based explanations for corporate hedging

Corporate risk-management practice can also be explained by firm management incentives. These theories model the manager's decision-making position, in which rational utility maximization or other behavioral factors are decisive. Risk management on these grounds is not necessarily in line with increased shareholder growth defined as corporate objective function.

Jensen and Meckling (1976) first examine corporate financial questions with the condition that firm management will maximize expected utility for the entire duration its life. Using this as a starting point, Stulz (1984) models the optimal (from a manager's perspective) hedging strategy. Because the manager generally can carry out hedging transactions with less favorable conditions than the firm can, and his revenues come predominantly from the firm, the manager can reduce fluctuations in his own income through corporate risk management. This type of risk management increases corporate value if it decreases the corporate management's compensation expected for non-diversified risk (Smith and Stulz, 1985).

In the DeMarzo and Duffie (1995) model, hedging creates value because it reduces information asymmetry surrounding investments and firm management effectiveness. Because management's aim is to prove its own capability, it has an interest in making results independent of those hedgeable risk factors on which it has no influence. Hedging that is optimal for management will also be optimal for shareholders if accounting reports that form the basis for management assessment handle hedging results together with operating results. Questions of accounting for hedging transactions are decisive, but are beyond the scope of this thesis[28].

Breeden and Viswanathan (1998) also trace corporate risk management to information asymmetry. Because management performance can be better assessed because of hedging, managers with better skills will be more likely to hedge, while those less skilled will not find it in their interest to decrease the volatility of results.

[28] The topic is discussed from an accounting perspective by Tardos (2003), and Fekete et al. (2008) in Hungarian.

Kahneman and Tversky (1979) note that individual decision-making is in many cases irrational, or is not consistent with preferences arising from the expected utility. Behind this irrationality are psychological factors influencing the individual; a description of this and motivations for individual decision-making are examined by behavioral finance. Corporate management's risk-management decisions are also influenced by several such psychological factors – overreaction, herding, certainty effect, etc. - (a detailed description can be found in Molar, 2006). Michenaud and Solnik (2008) model optimal hedging based on the regret theory. According to this theory, when making a decision, the decision-maker takes into consideration not only the expected utility, but also the loss of utility due to expected regret that will be experienced in the event that the hedging transaction has a negative value.

Irrelevance of corporate risk management	Miller and Modigliani (1958, 1963)		
Motives of corporate risk management	Value explanations of hedging through market imperfectnesses	Taxes	Smith and Stulz (1985)
		Financing	Myers (1984) Smith and Stulz (1985) Lessard (1990) Froot et al. (1993) Tirole (2006)
		Transaction costs	Dufey and Srinivasulu (1984)
		Information asymmetry	Tirole (2006)
	Incentive based motives of hedging	Manager incentives	Smith and Stulz (1985) Stulz (1984), Breeden and Viswanathan (1990), DeMarzo and Duffie (1992) Tuffano (1996)
		Irrational reasons	Michenaud and Solnik (2008)

Table 2: Motives of corporate risk management

Source: own edition

Theories proving corporate risk management with funding or incentive reasons are supported by empirical experiences, while explanations connected with taxation or transaction costs were not confirmed (Hommel, 2005).

2.3 Role of funding liquidity in risk management

Liquidity as a financial concept is fundamentally used in two senses. *Market liquidity* relates to sale of products traded on the financial markets, and reflects under what conditions it is possible to trade larger quantities. A detailed summary of literature on financial market liquidity and on the possibilities for measuring it has been offered by Michaletzky (2010), and Váradi (2012). The other interpretation of liquidity is *funding liquidity*, which means ability to fulfil payment commitments and relates primarily to corporate management[29]. Havran (2010) presents the literature on corporate liquidity and models liquidity management. The above two interpretations of liquidity mutually define each other; Brunnermeier and Pedersen (2009) analyze the correlation between trader funding liquidity and market liquidity. Acerbi and Scandolo (2008) highlight a third aspect of liquidity, the entire *financial system's liquidity*. An example of lack of liquidity at a system level was the financial market "drought" phenomenon resulting from a general lack of confidence in 2008 after the bankruptcy of Lehmann Brothers[30].

The classic economic theory starts with perfect market and funding liquidity conditions. The models – whether equilibrium and arbitrage models explaining market returns or Black-Scholes types of model frameworks of derivative instrument pricing – assume that trade can occur on the market at the given price, in unlimited quantities, and immediately (unlimited market liquidity), as well as that the market players can place deposits and take credit in unlimited quantities at a risk-free interest rate (unlimited funding liquidity). This thesis focuses on funding liquidity and does not examine market liquidity. In reality, funding liquidity is not unlimited, firms' supplementary funding comes at a cost, and it can even be the case that even with a credit spread it is impossible. Insufficient funding means

[29] Virág and Kristóf (2005) work on models based on bankruptcy probability index numbers.
[30] Several studies have presented this phenomenon, including Király et al (2008).

that the firm cannot fulfil its payment commitments, which can mean bankruptcy but can also mean lack of positive present value investments (Lessard, 1990). Corporate risk management creates value by decreasing the likelihood that financial distress will occur, as was discussed in the previous subsection.

I will offer a detailed presentation of two of the theories analysing the effect of hedging on firm value in the presence of limited funding liquidity: the models of Froot et al (1993), and Tirole (2006). Both models simplify corporate production and hedging decisions down to two periods, assuming that the hedging transaction (as it is in exact opposition to the basic position) generates no risk or cash flow (aside from any fees known prior to the transaction), and that the hedge occurs on a level that allows avoidance of bankruptcy.

2.3.1 The Froot-Scharfstein-Stein model

The analysis of Froot et al. (1993) is based on interconnected corporate investment and financial decisions. If external financing has a cost, hedging creates value by ensuring a certain level of internal financing resources and so investments with positive net present value can be implemented.

The model assumes that raising financing externally – both equity or debt type – is costly and this cost is an increasing function of the raised fund. The cost of external financing can arise from direct costs of financial distresses, like administration, transaction or legal fees, and indirectly, it can appear in form of underinvestment or decreasing competitiveness. On the other hand external financing has some cost deriving from the information asymmetry between the management and the external investor. The other assumption of the model is that the net present value of the investment is a concave function of the invested amount. The decreasing marginal value of the project can be explained by technological reasons (decreasing return to scale) or by taxation rules.

The model contains two periods, the liquid asset (cash-flow) realized at the end of the first period can be used for investment at the beginning of the second period. Then the corporate profit and value of the firm derives from the revenue of this investment.

The firm can decide about the hedging of the stochastic asset at the beginning of the first period.

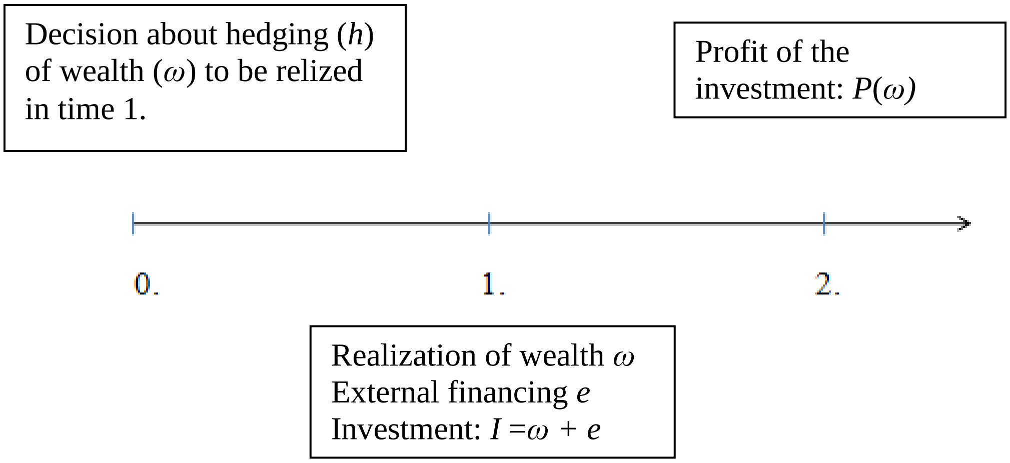


Figure 2: Froot-Scharfstein-Stein model

Source: based on Froot et al. (1993)

The following optimization problem is to be solved at the end of the first period:

$$P(\omega) = F(I) - C(e) \rightarrow \max \tag{17}$$

$$I = \omega + e \tag{18}$$

$$F(I) = f(I) - I \tag{19}$$

Where:

P: profit function;
ω: liquid asset realized at the end of the first period;
I: investment of the first period;
F(*I*): corporate net present value as a function of the investment;
f(*I*): expected level of output;
e: amount of external financing;
C: cost function of external financing.

According to the first order condition:

$$f_I = 1 + C_e \tag{20}$$

The indices refer to the partial derivatives.

Consequently the extent of the investment is to be increased as long as the marginal utility of the investment exceeds the marginal cost of external financing. We used the fact that the extent of the investment at the end of the first period depends exclusively on the external financing, as ω is given by then. The cost of financing reduces the optimal extent of the investment, as the marginal return has to cover the financing costs too, and *f* is supposed to be concave.

The profit function has a maximum if its second derivative according to ω is negative. Using the optimal investment (I*):

$$P_{\omega\omega} = f_{II}\left(\frac{dI^*}{d\omega}\right)^2 - C_{ee}\left(\frac{dI^*}{d\omega} - 1\right)^2 \tag{21}$$

Equation (5) can be written in the following form:

$$P_{\omega\omega} = f_{II}\,\frac{dI^*}{d\omega} \tag{22}$$

Hedging by reducing fluctuation in internal resources creates value, if the profit reduction caused by negative outcomes exceeds the gain of the favourable outcomes, that is, if profit is a concave function of ω. If there is a tradable asset correlating with ω, and hedging has no effect on the volume of ω, perfect hedge is optimal only if Equation (22) has a negative value. The following two conditions need to be satisfied for that: the marginal return of investment needs to be decreasing and an increase of the internal resources needs to have a positive impact on the optimal investment level.

According to Equation (21) the concavity of the profit function and the necessity of hedging derive partly from the concavity of the production function and partly from the convexity of the cost function. Therefore the rationale of hedging is the consequence of investment and financing considerations.

The investment opportunities are unchanged in the above analysis; they are independent from the random internal resources. The model can be extended in order to investigate the optimal hedging, if the underlying risk affects also the investment opportunities (for example an appreciation of the domestic currency is followed by narrowing export-markets). The initial equations in case of linear hedging instrument are the following:

$$\omega = \omega_0 (h + (1-h)\varepsilon) \tag{23}$$

$$F(I) = \theta f(I) - I \tag{24}$$

$$\theta = \alpha(\varepsilon - \bar{\varepsilon}) + 1 \tag{25}$$

Where

h: hedging ratio;

ε: return on hedging position[31], assumed to be normally distributed with a mean of 1 and standard deviation of σ;

α: correlation between investment opportunities and risk to be hedged.

At the profit maximizing hedging ratio the risk factor has no effect on the marginal profit of the internal resources, that is:

$$h^* = 1 + \alpha \frac{E\left[f_I P_{\omega\omega} / \theta f_{II}\right]}{\omega_0 E\left[P_{\omega\omega}\right]} \tag{26}$$

If the fluctuation in the internal resources has a positive correlation with the investment opportunities, the optimal hedge ratio is less than 100% (both P and f are concave functions), as the need for internal resources is partly hedged by their enhanced value. Similarly, it can be shown that a negative α leads to an overhedge in the optimum, as good investment opportunities arise if the internal resources are low.

[31]In case of forward agreement, it is the quotient of the forward price at maturity and the initial forward rate.

The optimal hedging ratio is also affected by the relationship between the risk factor and the financing costs. An overhedge can be justified by increasing financing costs in case of negative shocks, as it allows the firm to raise less external fund if it is more expensive.

Hedging helps to transfer cash-flow among different future states or different dates. The *hedging instrument* is *selected* to optimize this transfer. If investment and financing opportunities are given, or the risk factor correlates with both return and cost of investment, hedging strategies with linear payout function (like forwards) ensure the optimum. In case of state dependent investment opportunities, non-linear instruments (options) are optimal. Brown and Toft (2001) had the same result; they calculate the payout function of the optimal hedging strategy analytically.

2.3.2 The Tirole model

Jean Tirole (2006) models the corporate financial problems through *agency-based* considerations.

As a consequence of corporate ownership being separated from corporate management, information asymmetry gives rise to moral hazard, because the aims followed by the corporate management and the provider of the capital necessary for the firm’s operation (whether equity or debt) do not necessarily match. In this model, the entrepreneur who is leading the project needs external funding alongside his own funding resources, yet he can realize private profit even if the investment itself fails. Because the provider of the funding is also aware of this, the firm’s funding is only ensured if investors see a yield on their investment even in the presence of risk from information asymmetry; that is, it’s guaranteed that the management represents the investors’ interests. According to the basic version of this model, the entrepreneur only accesses external funding with a specified downpayment proportion. The proportion of own resources ensures that management makes the return on the project a top priority in comparison with its private profit. In the event of insufficient own resources, a credit rationing occurs – even if the entrepreneur would be willing to pay a surcharge for funding, he is denied access to it.

In this model *liquidity risk* appears as a random supplementary funding need that has corporate management no effect on. The single-stage decision then becomes a multistage decision, and after the project is launched, cash-flow (whether negative or positive) of unpredictable extent can be expected.

He can only supply this supplementary funding need from the market if the magnitude of the liquidity shock is smaller than the pledgeable income ensuring adequate incentive to the borrower. The project is, however, worth continuing as long as this liquidity need remains less than the expected income of the project (without supplementary investment, distributable income is zero).

In this model both the entrepreneur and the investor are risk-neutral, so their only aim is maximization of achievable profit. *Risk management creates value because the asymmetrical information situation means that positive net present value projects will not gain access to supplementary funding sources in the event of liquidity shock (beyond a certain measure), as the borrower cannot credibly pledge the full net present value, because with this income distribution the creditor does not see borrower incentive as sufficient to ensure project success.* Tirole shows that cost-free hedging creates value because in this way the future “liquidity shock” maximum at which the project can continue can be deterministically defined, and the entrepreneur’s expected utility is greater than without hedging, where continuing depends on a random risk factor. It can be demonstrated that full hedging of risk decreases the unit cost of the investment, thus increasing the borrower’s utility.

With this kind of explanation of risk, risk hedging is equivalent to provision of a conditional credit line of adequate size. Provision of the credit line is more advantageous if the risk is not well defined and hedging instruments are not easily available. Hedging is more advantageous because of possible management assessment, as it renders the project’s ability to continue independent of funding available as a result of external influence.

Tirole calls readers’ attention to the fact that there are situations in which only *partial hedging* is optimal. Insofar as the firm occupies a dominant market position, the full hedged quantity can exceed the output that ensures maximum profit. Another important factor is the serial correlation of incomes. In the event of positive correlation, better revenue comes with better growth potential and better funding options, making full hedging unnecessary (similar to the model in the previous section). In the case of negative correlation, however, because the better performance is followed by worse options, it is more advantageous to withdraw surplus liquidity from the firm. It is uncertain whether the aggregated risk level can be reduced; if not, then risk reduction will not be cost-free. In that case, at the optimal hedging level the marginal cost of the hedge matches the marginal benefit of the hedge. If hedging the risk requires some sort of special knowledge, this also translates into a cost. Finally, full hedging of risk can cause management to become “lazy”, which results in agent costs.

In the model of Froot et al, as well as in the model of Tirole, who further developed the analysis of the former, the role of risk management and hedging can be interpreted from a funding perspective. Both models assume a risk-neutral (linear profit) corporate utility function, while inclusion of external funding sources is costly. Froot et al do not explain this cost function but accept it as given, while with Tirole, costs arise from the principal-agent problem, because the financier is only willing to provide funding to a certain extent. Without a sufficiently large own contribution, the financier will not take the risk of funding even in exchange for a surcharge. The reason for hedging to exist comes from the fact that it can help reduce funding costs, and thus the expected profit value, and the firm’s value grows as a result.

2.4 Optimal hedge ratio, the Holthausen model

Holthausen (1979) analyses the production and hedging decision of a profitmaximizing firm, assuming a concave corporate utility function. The firm produces a single product in a perfect market, the price of the product is stochastic (p), the cost of it, $c(x)$, is a growing function of the quantity (x). The firm decides in time zero about the production quantity to be realized at the end of the period and also about the quantity (h) to be hedged. The selling price can be fixed at the forward rate (b). Assuming the existence of a Neumann-

Morgenstern type corporate utility function that needs to be concave [32], the optimal level of production and hedging maximizes the profit dependent expected utility.

$$\underset{x,h}{Max} EU(\Pi) = \int_0^\infty U\left[p(x-h) + bh - c(x)\right] f(p)dp \tag{27}$$

Where *f(p)* is the density function of the price.

In order to get the optimal quantity of production and hedge, the following derivatives have to equal to zero:

$$\frac{\partial EU(\Pi)}{\partial x} = \int_0^\infty U'(\Pi)\left[p - c'(x)\right] f(p)dp = 0 \tag{28}$$

$$\frac{\partial EU(\Pi)}{\partial h} = \int_0^\infty U'(\Pi)\left[b - p\right] f(p)dp = 0 \tag{29}$$

The optimal production quantity is less if the price is stochastic, than in case of certain price equalling the expected value of the random price[33] and the difference increases with the risk aversion of the firm[34]. If derivative market exists for the product, at the optimal production level the marginal cost equals to the forward rate, independently from the corporate risk aversion or expectations about the future price movements. Those have an impact only on the hedged quantity, but not on the production.

In order to investigate the optimal hedging, (29) is rewritten in the following form:

$$E\left[U'(\Pi)(b-p)\right] = EU'(\Pi)E(b-p) + \mathrm{cov}\left[U'(\Pi), -p\right] = 0 \tag{30}$$

[32] In case of risk neutral and risk-loving firms, the second derivative is not negative, so the function has not got a maximum.
[33] The analysis can be found in Sandmo, 1971.
[34] It also derives from the concavity of the utility function.

So optimal hedging quantity depends on both the relation of the forward price to the expected spot price at maturity and the corporate risk attitude. Perfect hedge is optimal, if forward price equals to the expected price (b=E(p)), independently from the risk appetite, as in this case the first term of the right hand side of (30) is zero, so the covariance term has to be zero as well to reach the optimum. That means the profit shall be independent from the price. If forward price is lower than the expected spot rate (b<E(p)), the firm will hedge less than the produced quantity, it can even be optimal to take an opposite position ($h<0$), as the first term of the right hand side of (30) is negative, so the covariance term shall be positive. In case of underhedge increasing price increases the profit, but lowers the marginal utility, so an increase of the price has negative impact on both parts of the covariance. The extent of underhedge decreases with the increase of risk aversion. It can be shown similarly that forward price exceeding the expected price leads to overhedge ($h>x$), the firm sells on forward more, than the produced amount. The speculative position decreases with the increase of corporate risk aversion.

According to the above analysis firms having insufficient access to futures markets can increase expected corporate utility by reducing their output.

Higher risk in form of increased price volatility leads ceteris paribus to increasing hedged amount in optimum, as the available growth in utility is also higher.

3 FINANCING NEED OF HEDGING POSITION

The models detailed in the previous chapter contained a single period hedging decision, although the problem of hedging is described in two-period framework. Consequently optimal hedging is determined exclusively by the production- and price-distributions at maturity. As the interim period is not investigated in the model, hedging generates no cash-flow during the lifetime of the hedging transaction and so no funding need arises.

In practice hedging positions need *financing* from several reasons: *upfront fees* have to be paid for derivatives with asymmetric payout function (like options); mismatch of the hedging position and the underlying risk (*basis risk*) or the daily settlement of mark-to market of futures have cash-flow consequences. In case of trading on exchange, a certain amount of initial margin is required and also a minimal level the so called maintenance margin has to be ensured during the entire lifetime of the transaction. Although the profit or loss of derivatives in the over-the counter (OTC) market does not need to be settled on a daily basis, in practice the partners require in most of the cases some initial or interim collateral to reduce the counterparty risk (Korn, 2003). The new European regulation (EMIR, 2012) enacts the central clearing of even OTC transactions above a certain level, in order to reduce partner-risk and so the vulnerability of the financial system.

ISDA (International Swaps and Derivatives Association) contracts that provide the legal framework of derivative trading, are a kind of credit contract, their annex contains also credit risk mitigating elements like collateral obligations or covenants. As a consequence of the crisis these documents were supplemented by the Credit Support Annex (CSA) that dispose of mutual collateralization obligations even in case of the largest and thought to be safest counterparties or banks.

Furthermore, even if a firm has no financing obligation connecting to its derivative transactions, the non-realized loss of the position increases the exposure of the bank toward the company that restricts the availability of further financing. Consequently not only the exchange traded derivatives, but also OTC positions are path dependent, their profit depends on the price evolution during the tenor.

Therefore, the availability of financing is critical for the hedging position as well. The maturity of the derivatives used for hedging can be measured in years, and their financing need affects the financing opportunity of the company.

Although the analysis of Froot et al. mentions the trade-off between the variability of future cash-flow and the fluctuation of cash in the interim period if the hedging position is to be financed, they do not analyse this problem further.

The financing need of the hedge position appears in the analysis of Anderson and Danthine (1983). In their multi-period model hedging occurs on several dates and the mark-to-market value of the hedging position (futures) is settled in each interim period. Nevertheless the model does not include any financing constraint or credit spread, so cash-flow can be converted simply to maturity at the riskfree rate.

The liquidity risk of the hedging position appears in the 2000's in the theoretical models. Mello and Parson (2000) investigate optimal hedging strategies by considering liquidity aspects and they conclude that financial constraints lead to the suboptimality of both cash-flow variance minimizing and corporate value variance minimizing hedging strategies. Optimal hedging minimizes the variance of the marginal value of corporate cash; it switches cash to the outcomes, where the marginal utility is the highest.

In the model of Almeida et al (2011) corporate financial decisions – also hedging decisions – are determined by the availability of financing resources in the future. If *outside financing is limited*, corporations prefer projects generating cash in short term and operative hedge is optimal instead of financial hedge. The practice supports the above statements, as large corporations having better access to external financing, apply financial hedging.

Broll and Wahl (2011) prove in case of exporting firms that liquidity constraints lead to *underhedge* of the exposure and also to reduction of export activity.

In the models detailed in the thesis, the optimization criterion is not the maximization of the expected profit, but the maximization of the (concave) corporate utility function. Although utility function is interpreted for individuals, the corporate utility function is used to incorporate the explicit and implicit costs of financial distresses. Liquidity risk is calculated through the modelling of the margin account, providing that the firm has no or limited financing source in case of a margin call (Deep, 2002).

The unavailability of financing derives from the fact that internal resources are too expensive to hold for that purpose and external investors are not willing to provide financing or they require a spread because of the information asymmetry, as it cannot be seen from outside whether the losses of the derivative positions are caused by prudent hedging or speculation. Faff and Nguyen (2007) get to similar conclusion by analysing the relationship between corporate value and corporate derivative usage. They found that the usage of derivatives, contrary to the expectations, affects corporate value negatively. The reason for that discount is the information asymmetry between the management and the outside investors[35].

The other way of modelling liquidity risk is based on the financing costs deriving from the credit spread to be paid to collateralize the loss of the position (Korn, 2003).

The latest two models (Deep, Korn) contain a concave corporate utility function that reflects constant relative risk aversion (CRRA). The following section introduces these models.

3.1 *Hedging in case of limited margin availability– Deep model*

The risk investigated by Deep (2002) can be perfectly eliminated by futures hedge. The future corporate output (π) is given; risk derives from the uncertainty of the future price of the product. The price is supposed to follow geometrian Brownian motion with a drift equalling to the riskfree rate.

$$dS_t = rS_t dt + \sigma S_t dw_t \tag{31}$$

Where S_t is the spot price in time t, r stands for the riskfree interest rate, σ is the volatility of the price-change and dw_t – change in the Wiener process – denotes the stochastic part of the price movement.

[35] It is important to note that this research investigates the usage of derivatives, independently from the underlying exposure of the company.

As the expected growth of the price is the riskfree rate, the process of the forward rate – using Itô-lemma –is a martingale[36].

$$dF_t = \sigma F_t dw_t \tag{32}$$

With this simplification the speculative motive of the hedge – shown is the model of Holthausen – can be eliminated, the profit or loss of the hedging position has no impact on the optimal hedging.

The firm hedges its exposure with short futures, the hedged amount (θ_t) can be adjusted on any interim dates. The value of the hedge (futures) position is settled on the margin account (X_t) on each interim dates, so the value of the margin is also stochastic:

$$dX_t = rX_t dt + \theta_t dF_t \tag{33}$$

The firm has a certain amount of cash (X_0) to use as margin in order to open the hedging position, but it cannot get further financing if the margin account drops to a minimal (K) level that have to be maintained and the firm receives a *margin call*. The inability to meet the margin obligation leads to liquidation of the position and so the original exposure becomes unhedged. Although the model assumes the unavailability of financing, a credit line can be built in the model by adjusting the values of K and the initial margin of X_0.

Table 3 shows the probability of liquidation of the hedge position for different maturities, initial margin amount and price volatility. The price follows geometrian Brownian motion described in Equation (31); other stochastic models of price movement are presented in chapter 5.

[36] The drift of the forward rate process is the difference between the drift of the underlying asset and the riskfree rate that is zero in our case. (see Equation (48)).

Probability of liquidation			
Volatility	Initial margin (X_0/F)	T=26 weeks	T=52 weeks
15%	0.05	55%	65%
	0.10	29%	44%
	0.25	1%	9%
	0.50	0%	0%
	1.00	0%	0%
20%	0.05	62%	69%
	0.10	41%	48%
	0.25	8%	13%
	0.50	0%	1%
	1.00	0%	0%

Table 3: The probability of liquidation of the hedging position

Source: own calculation based on Deep (2002)

The above results are based on Monte Carlo simulation by running 1000 realizations. In case of an initial margin requirement of 10% the probability of liquidation of a 1-year position is 44%. As the initial margin in reality is below 10%, hedging corporations have to calculate upon future financing need that has to be managed without financial distress.

The goal of corporate management is to maximize the expected utility of corporate value – the sum of the production and the margin account – at maturity. Assuming constant relative risk aversion (CRRA, see chapter 2.) in corporate utility function, optimal hedge maximizes the following equation:

$$\max_{\pi t} \mathrm{E}_t\left[\frac{(X_T + \pi F_T)^\gamma}{\gamma}\right]; \qquad 0 < \gamma < 1^{37} \tag{34}$$

subject to $X_t \geq K$.

Deep solves the optimization with the help of stochastic dynamic programming. The optimal hedging problem is a stochastic control problem that has only numerical solution because of the non-linearity of the partial differential equation to be solved.

[37] Here γ denotes not the risk aversion, but (1 minus risk aversion). As its value is 0.5 in the analysis the two are equal.

Factors influencing the optimal hedging strategy are: corporate exposure, maturity of hedge, volatility of the risk factor, available financial resources and the corporate risk attitude.

When deciding about hedging, corporations have to choose between two types of risk: the lower the uncertainty of the future price of production (*value-risk*), the higher the risk of liquidation (*cash-flow or liquidity risk*) will be. It can be seen intuitively that a higher margin account balance means less constrained liquidity. Figure 3 shows the effect of available financing sources and the time to maturity, assuming the risk factor follows geometrian Brownian motion with an annual volatility of 15% and a drift rate equalling the risk-free rate (5%), the level of corporate risk aversion (1-γ) is 0.5.

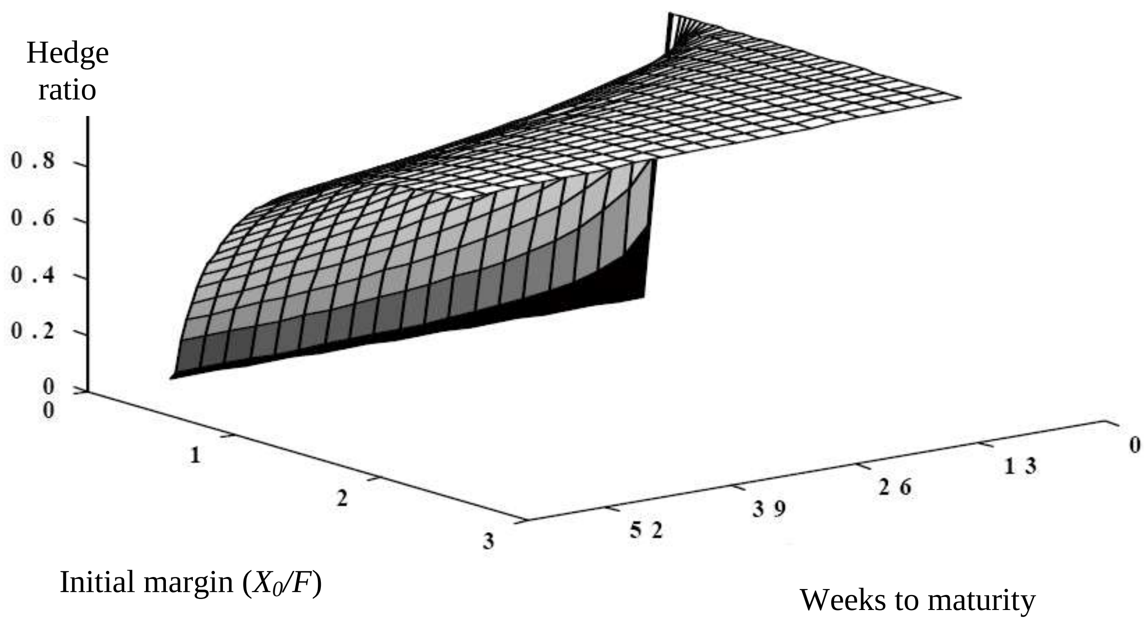


Figure 3: Optimal hedge ratio as a function of initial margin and maturity

Source: Deep (2002), Figure 5.1

Optimal hedging ratio is a negative function of the *time to maturity* and a positive function of the *available financing resources*. The corporate risk aversion is in inverse ratio to the level of financing resources. The higher risk aversion has a similar effect as the higher constraints, namely both decrease optimal hedging ratio, since the utility reduction deriving from the termination of the hedge is larger.

Deep model originates underhedging in financing decision. The model of optimal hedging concludes that financial difficulties to maintain the position lead to the reduction of the corporate hedge ratio of the predetermined output.

3.2 *Financing cost of the hedge position – Korn model*

The liquidity risk of the hedging transaction is caused in the model of Korn (2003) not by the potential liquidation of the position, but the extra cost of financing. The model assumes that the firm is able to get financing in the market, but not at the risk-free interest level (*r*), so it has a cost. The cost of financing, and so the liquidity risk of hedging is higher, if the corporate specific credit spread (*s*) is higher. Although the model contains a constant credit spread, but it can be extended with a need-dependent credit spread (see chapter 4), by increasing of which to infinitive unavailable financing can be simulated.

In the basic model corporation decides about the quantity of production (*Q*) that will be realized in 2 periods. The selling price of the output (*P*) is stochastic, generating the risk to be hedged. Forward agreements are used for hedge, the forward rate process is supposed to be a martingale (as in the previous model). The firm can conclude hedging deals at both dates, initially and also in the interim period.

Figure 4 depicts the process, indices stand for the time.

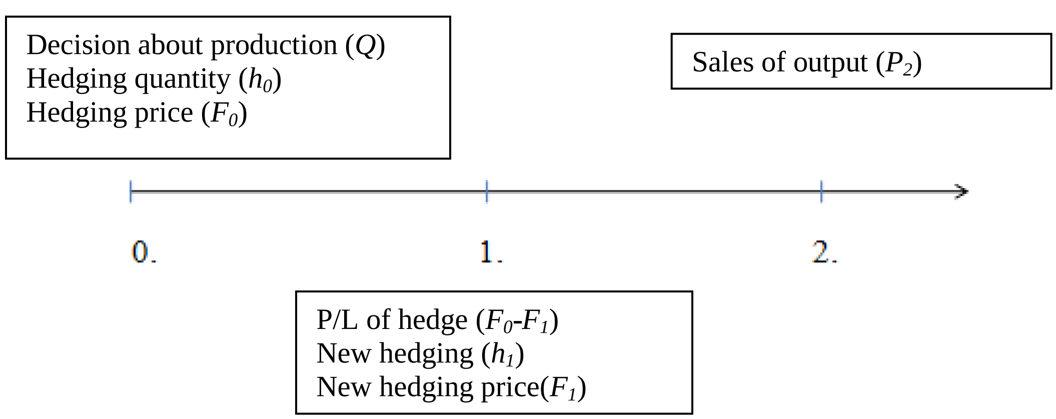


Figure 4: The process of corporate operation in the model of Korn

Source based on Korn (2003)

The corporate profit realized at the end of the second period (Π) consists of three parts: the operative profit, the profit or loss of the hedging positions and the cost of the collateral of the hedging deal.

$$\Pi = \underbrace{P_2 Q - c(Q)}_{\text{Operative profit}} + \underbrace{h_0(F_0 - P_2) + h_1(F_1 - P_2)}_{\text{P/L of the hedge}} + \underbrace{s \min\left[h_0 \frac{(F_0 - F_1)}{1+r};0 \right]}_{\text{Cost of the hedge}} \qquad (35)$$

The parameters of the equation are defined above.

The optimal hedging strategy, maximizing expected utility ($E[U(\Pi)]$) is to be determined in two steps, recursively.

In order to calculate the amount to be hedged at the first (interim) date (h_1), Equation (35) is to be maximized at the already known level of Q, F_1 and h_0.

$$\max_{h_1} E_1[U(\Pi) | F_1, Q, h_0] \qquad (36)$$

The first order condition that ensures the existence of the maximum as the function is concave:

$$E_1[U'(\Pi)(F_1 - F_2)] = 0 \qquad (37)$$

As the expected value of the forward rate at maturity is supposed to equal to the forward rate at time 1, ($E_1(F_2)=F_1$), the equation is held if the covariance of the two terms of the product is zero, namely profit-function is independent on F_2.

According to that, the optimal hedging amount at time 1:

$$h_1^* = Q - h_0 \tag{38}$$

At the first date the entire output is to be hedged, independently from the corporate financing cost (s), as no further collateral obligation will arise. At time zero, substituting Equation (38), the profit-function is the following:

$$\Pi^* = F_1 Q - c(Q) + h_0 (F_0 - F_1) + s \min\left[h_0 \frac{(F_0 - F_1)}{1+r} ;0 \right] \tag{39}$$

In the absence of financing costs (s=0), expected utility can be maximized, if:

$$E_0[U'(\Pi^*)(F_0 - F_1)] = 0 \tag{40}$$

Similarly to the above presented hedging at time 1, the independency of the profit-function from the forward rate (F_1) can be ensured by hedging the entire production.

$$h_0^* = Q^* \qquad \text{and} \qquad h_1^* = 0 \tag{41}$$

In the model of Korn the production quantity is also an endogenous variable that can be determined through Equation (41) and the corporate utility function:

$$E_0[U'(\Pi^*)(F_1 - c'(Q))] = 0 \tag{42}$$

That holds, if:

$$E_0[U'(\Pi^*)](F_0 - c'(Q)) + \text{cov}_0[U'(\Pi^*), F_1] = 0 \tag{43}$$

The optimum is achieved, if the covariance term of Equation (41) is zero, so the optimal output is at the level, where the marginal cost of production equals the initial forward price (F_0). This result suggests perfect financial hedge, similarly to the above presented models of Holthausen or Froot et al.

If financing is costly ($s > 0$), hedging increases value by reducing the uncertainty of corporate profit, on the other hand, it has a cost that affects expected profit negatively. Consequently the optimal output will be less than in the cost-free case and the optimal hedging ratio is below 1. Korn proves that a hedge ratio less than zero – that is an exposure in the same direction - cannot be optimal due to the costs of any derivative position. Optimal hedge ratio can be calculated in view of corporate utility function and the process of forward price. The analysed model assumes that forward rate is lognormally distributed and the utility function reflects constant relative risk aversion (CRRA). Based on these assumptions Korn proves indirectly the following bounds of optimal hedge ratio[38]:

$$\frac{1+r}{1+r+s} \geq h_0^* / Q^* \geq \bar{c} / F_0 \tag{44}$$

Where $\bar{c}$ stands for the average cost of a unit produced.

In order to calculate optimal hedge ratio Korn takes the same parameters as Deep: risk-free interest rate of 5% and volatility of forward price of 15%. The cost function is not defined, average cost is 0.1 and both periods of the model are 1 year.

The optimal hedge ratio is given by maximizing the expected value of the utility (45).

$$U = \frac{(\Pi^*)^{(1-\gamma)}}{1-\gamma} \tag{45}$$

Where:

U: utility
$\prod^*$: profit in case of optimal hedging
γ: risk aversion

[38] If hedge ratio is otside those bounds, a loss (negative profit) occurs with positive probability that cannot be optimal for a risk averse corporation.

Solving the optimization numerically with the above parameters, Figure 5 shows the optimal hedge ratio as a function of corporate credit spread (*s*) and risk aversion (γ)[39].

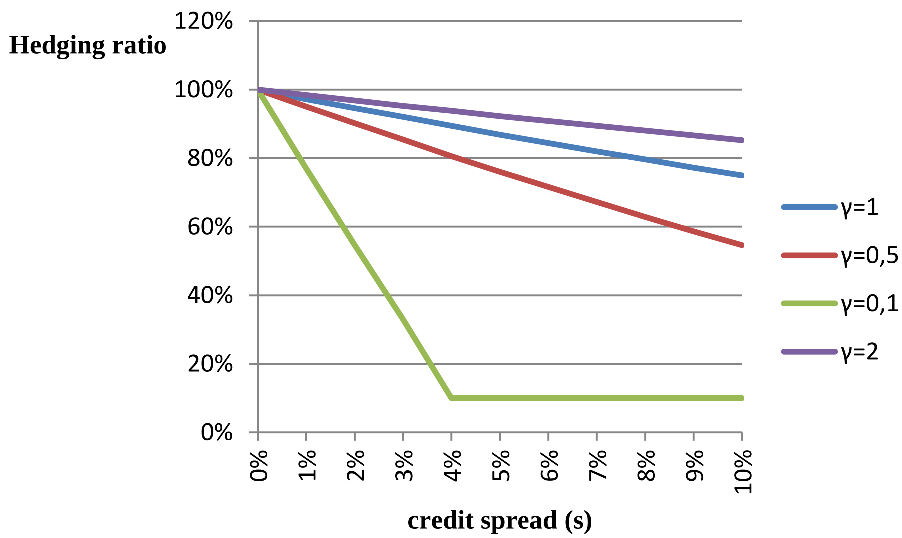


Figure 5: Optimal hedging in Korn's model

Source: own simulation with antithetic variates based on Korn (2003)

As Figure 5 illustrates, perfect hedge is optimal if the firm gets financing at the risk-free interest rate. One percentage point increase of the credit spread leads to a five percentage point reduction of the optimal hedge ratio in case of a corporate risk aversion of 0.5 (γ=0.5).

As risk aversion decreases (decreasing γ*), the optimal hedge ratio also declines,* since the utility of hedge that offsets the interest cost of the hedge, is lower.

The costs of production impact the hedging policy significantly. The ratio of average cost of production to the forward price is the lower bound of the optimal hedge ratio, as this level of hedge ensures that the revenue covers the costs of operation at least[40].

The increase of average cost enhances the minimal level of the hedge ratio, since profit will be lower, and the slope of the utility function is higher at smaller values (the firm is more sensitive to negative outcomes), so utility achieved by hedge is also higher. However it is important to note, that the above relationship refers to the hedge ratio, while the optimal

[39] Risk aversion is zero in case of risk neutrality and the upper extreme value of 2 is the individual risk aversion determined by Blume and Friend (1975).

[40] The initial forward price exceeds the average cost; otherwise it is not worth investing in the project.

level of output and the amount of hedge can essentially decrease in the presence of financing costs.

The volatility (standard deviation) of the risk factor has a dual effect on optimal hedge. On the one hand the higher volatility of forward rate (higher risk) increases the optimal hedge ratio of a risk averse corporation. On the other hand higher volatility also increases the expected value of the financing costs of the hedge that has a negative effect on the optimal hedging level. The result of the two contradictory effects is not obvious. In case of the parameter-set investigated by Korn (r=5%, γ=0.5, average cost=10%, F_0=1, F lognormal with a mean of 1 and three different values of volatility: σ=0.1; 0.15; 0.2), increasing volatility causes a rise of the optimal hedge ratio.

The question arises, how optimal hedging evolves, if options are also available, as bought options do not induce financing need during their lifetime. However, the upfront fee of options makes this strategy too expensive and so suboptimal for a constrained firm.

3.3 Comparison of liquidity adjusted hedging models

The above detailed two models describe *funding liquidity risk* deriving from the financing need of the hedge position differently and their conclusions also differ partly.

The selling price of the *production* (P) is *risky* in both models, and therefore corporate revenue and profit are also stochastic. The product is traded in the market and it can be sold by (short) forward or (short) futures agreements any time, in any quantity, at the actual market price (F_t). It is also common in the two models that the spot and forward rate of the underlying asset follow geometrian Brownian motion and the drift of the spot price process equals the risk-free rate of return, consequently the forward rate process is a martingale. This assumption simplifies the calculations, as the expected value of the hedge position is zero, so forward or futures sale has no speculative reason. Both models investigate optimal hedging based on a corporate utility function that reflects constant relative risk aversion (CRRA).

The main difference of the models is in the hedging position. Deep uses futures for the hedge, the value of which is settled on a daily basis on the margin account, so liquidity risk derives from the financing limits in case of a margin call.

In the model of Korn hedging occurs by forward agreements that have to be collateralized (in cash) in case of loss at a single interim date during maturity. Liquidity risk appears in form of the credit spread of the loan taken to meet collateral obligation.

The model of Deep does not include production costs; optimization is based on profit that is the sum of operating income (price of the output at maturity) and financial income (value of the margin account). The produced quantity is an exogenous variable of the model; while in the model of Korn production costs affect both optimal output and the minimal hedging ratio.

Table 4 summarizes the ceteris paribus impact of the hedging ratio influencing parameters - parameter values are specified above - that can differ in the two models.

	Deep	**Korn**
Risk aversion (γ)	↓	↑
Volatility of the risk factor (σ)	↓	↑
Credit spread (s)	--	↓
Financing resource (X)	↑	--
Hedging period (t)	↓	↑
Production costs ($c(Q)$)	--	↑

Table 4: Ceteris paribus effect of factors influencing optimal hedging in the models of Deep and Korn

Source: based on Deep (2002) and Korn (2003)

Increasing *risk aversion* leads to decreasing optimal hedge ratio in the model of Deep, as the risk of liquidation of the hedge can be lowered by a smaller derivative exposure. However in the model of Korn the higher risk aversion implicates higher utility achieved by the hedge, so in spite of the enhanced financing costs, optimal hedge ratio will be higher.

The *volatility of the risk factor* affects both the potential loss of the underlying exposure and the costs of the hedge. These contrary effects have different result in the two models, in

Deep's model the latter is more significant, so increasing volatility leads to lower optimal hedge ratio, while in the model of Korn utility enhancement of the hedge exceeds the costs, so optimal hedge ratio increases with the volatility.

The parameters of *liquidity risk* have the same effect in models, the higher credit spread or the lower margin amount result in the reduction of optimal hedge ratio.

The *time to maturity* has similar impact as volatility, it increases risk of liquidation of the hedge position, therefore lowers optimal hedge ratio in the model of Deep, but in Korn's model utility enhancement of the hedge due to volatility increases the level of optimal hedge. Longer maturity means longer hedging period, but financing need appears only at a single date at Korn.

Korn model has the advantage being closer to reality, as the most frequently managed fx-risk is usually hedged in the OTC markets. These transactions are regulated by the already mentioned ISDA agreements, where counterparty risk is managed in the Credit Support Annex (CSA) that contains the conditions of collateralization. On the other side disadvantage of the model is that it investigates only one interim date, but the tenor of hedging can be measured even in years. The other shortcoming of the model is the lack of absolute financing constraint, here the firm is able to get financing unlimitedly at the given credit spread.

According to these considerations, I build a model based on the theory of Korn in the next chapter and the results of my model will be analysed in a multiperiod and constrained financing framework in chapter 5.

II. PART: THE OWN RESEARCH

4 MODELLING OPTIMAL HEDGING RATIO IN THE PRESENCE OF LIQUIDITY RISK

The following chapters contain the own results. This chapter investigates the optimal hedge ratio in a theoretical model that is based on the analysis of Korn. In the basic model the optimal hedging was influenced by two contradictory effects: the forward hedge increased the corporate utility by reducing the variance of the profit, on the other hand the credit spread to be paid for financing the hedging position as an explicit profit-reducing factor caused the fall of the utility.

In my model the expected value of the hedging position can differ from zero affecting the profit function; therefore the optimal hedge ratio can exceed 100 percent.

Furthermore, I analyse the effect of non-static financing costs, the credit spread is a function of the financing need as well. A multistage extension of the model and investigation of pregiven financing constraints are the topics of the fifth chapter.

4.1 The effect of expected value of the hedge position

The model of Holthausen (1979), detailed in chapter 2, the expected value of the hedge position affected the expected value of the profit and so the expected corporate utility. If the initial forward rate equals the expected spot rate at maturity, perfect (100%) hedge is optimal. In case of positive / negative expected value of the hedge position overhedge / underhedge becomes optimal.

The models of the third chapter analysed the optimal hedge ratio from financing perspective, assuming the expected value of the hedge position is zero, namely the initial forward rate and the expected spot rate at maturity are equal. This assumption simplifies the calculation, as only the effect of variance reduction is to set against the financing costs of the hedge position.

According to the modern portfolio theory (Markowitz, 1952) the forward rate equals to the expected spot rate at maturity only if the real drift of the process of the underlying product equals to the riskfree rate of return, namely the systematic risk of it is zero.

The expected profit of the forward position derives from the difference of the return of the underlying product and the riskfree rate that corresponds with the risk premium paid for the systematic risk of the underlying. Therefore an extra profit cannot be achieved by opening a forward position in itself, so the optimal hedge ratio is not worth to be changed because of the expected value of the forward position.

The forward price, shown in Equation (2) is the spot price enhanced compounded by the risk free rate, considering the eventual positive/negative cash-flow of possessing the underlying product. Contrarily, the expected spot rate at maturity is given as the spot rate compounded by the expected return that contains the risk premium of the product as well. In other words the expected value of the spot rate is the forward rate as a certainty equivalent, plus covariance of the spot rate and market return (it is the quantity of risk) multiplied by the market price of risk (λ) (detailed explanation in Medvegyev and Száz, 2010):

$$E(S_T) = CEQ_T + Cov(S_T, y_m) * \frac{r_m - r_f}{\sigma_m^2} = F_T + Cov(S_T, y_m) * \lambda \tag{46}$$

Where:
S_T: spot price in time T
$E(S_T)$: expected price in time T
CEQ_T: certainty equivalent in time T
y_m: market return until time T
r_m: the expected value of the market return (y_m)
r_f: riskfree rate until time T
F_T: forward price maturing in time T
σ^2_m: the variance of the market return

The expected future spot rate depends on the covariance of the future value of the asset and the market return. In case of positive covariance the expected future spot rate exceeds the forward rate, so selling (buying) on forward has a negative (positive) expected value. Similarly an opposite relationship causes the forward sell (47) to have positive expected value.

$$E(F_T - S_T) = Se^{rT} - Se^{\mu T} \tag{47}$$

Where μ stands for the expected drift of the spot rate.

The model assumes a company being exposed to the change of the market price of its product, so its revenue and profit bears market risk. The company has a *CRRA utility function* and we assume furthermore that hedging of this open position in form of forward agreements is available at the market.

Assuming the spot price (*S*) follows geometrical Brownian motion with an expected drift of μ and volatility of σ, the forward price (*F*) also follows a geometrical Brownian motion as it can be seen in Equation (48):

$$dF = (\mu - r)Fdt + \sigma F dw \tag{48}$$

The model is built up as follows: the company decides at time 0 about the hedging amount (*h*) of its given production quantity (*Q*), in our case the amount sold on forward. Maturity of the forward agreement and realization of the production occur at time 2, and during the lifetime of the derivative position the unrealized loss is to be collateralized at time 1.

Consequently the corporate profit realized is time 2:

$$\Pi = S_2 Q - c(Q) + h(F_0 - S_2) + k \min\left[h\frac{(F_0 - F_1)}{1+r}; 0 \right] \tag{49}$$

The indices refer to the time, the new parameter, *k* stands for the credit spread to be paid by the hedger company, *k* is considered to be constant.

The differences between this model and the model of Korn are the non-zero expected value of the forward agreement, the exogenous production amount and lack of adjustment of the hedged amount in time 1.

The optimal hedge amount (h), which maximizes the expected utility, meets the following requirement:

$$E\left[U'(\Pi) * (F_0 - S_2 + k \min[0; \frac{F_0 - F_1}{1+r}])\right] = 0 \tag{50}$$

Equation (50) can be written in the next form:

$$E[U'(\Pi)] * E\left[F_0 - S_2 + k \min[0; \frac{F_0 - F_1}{1+r}]\right] = -\operatorname{cov}(U'(\Pi); F_0 - S_2 + k \min[0; \frac{F_0 - F_1}{1+r}]) \tag{51}$$

The sign of the left hand side of Equation (51) is equal to the sign of the expected value of the short forward position, as the utility function is increasing. If the expected value is positive ($\mu<r$) equality holds only if the covariance term on the right hand side is negative. As the second variable in the covariance is affected negatively by S_2 and F_1 independently from the hedged amount, the negativity of the covariance requires the first part (in Equation 52) to be a positive function of the stochastic variables.

$$U'(\Pi) = \left[S_2 Q - c(Q) + h(F_0 - S_2) + kh \min[0; \frac{F_0 - F_1}{1+r}]\right]^{-\gamma} \tag{52}$$

In the absence of financing costs (k=0), this requires h (the hedging amount) to exceed the quantity of the production (Q). From this follows, that it is optimal to overhedge, similarly to the model of Holthausen (1979).

However funding liquidity risk (in the form of financing cost) reduces the optimal hedge ratio, as the effect of F_1 (being positively correlated with S_2) is positive for any positive value of h. The reduction of the optimal hedging depends on the level of the financing costs (k). It can be similarly shown, that the negative expected value of the hedge position causes a lower than 1 optimal hedge ratio, that is further reduced by the eventual financing costs.

In sum this means, that the hedging affects the corporate utility, since the financing cost and the expected value of the hedge position influence the expected value of the profit. The effect of the financing cost to the utility is always negative; the expected value can have both negative and positive impact; while utility increases through variance-reduction.

The result of this threefold effect is a function of the determining parameters: the corporate credit spread, the expected value of the hedge position and the corporate risk aversion factor.

The optimal hedge ratio of the above presented model differs from that of the model of Korn, since risk cannot be eliminated here perfectly, just at a given significance level, as the profit is the function of two not perfectly correlated risk factors (F_1 and S_2).

Despite of the positive correlation of the risk factors, under extreme circumstances the corporate profit can become negative at any hedging level. The worst outcome occurs if the short hedge position is to be financed because of the growing market price of the first period, but this higher market price is not used to complete the hedge position, and the falling market price causes an operating loss on the unhedged part of the firm's production.

The minimal hedged amount has to cover not only the operating costs, but the financing cost of the position as well. As the financing cost is an unlimited stochastic variable[41], this coverage can be ensured only at a given significance level. The lower bound of the hedging ratio (53) is the ratio of the average cost and initial forward rate reduced by the maximum financing costs at a certain (α) level [42]:

$$\frac{h}{Q} > \frac{\bar{c}}{F_0 - \frac{\Delta F_{1\max\alpha}}{1+r}k} \tag{53}$$

Where $\Delta F_{1max\alpha}$ is the maximum of the forward price change in the first period with a probability of α. This ratio ensures a positive end of period profit at any low level of the market price at maturity, even if the hedge position caused financing costs.

[41] As the price movement has no upper limit, the financing cost can be theoretically even infinitive.

[42] The deatails of the analysis are shown in Annex V.

The maximum of the hedge ratio is the level, where the financing cost and the negative value of the hedged position are counterbalanced by the realized higher operating income. Denoting the maximum of the change in the forward price by $\Delta F_{2max\alpha}$, the upper bound is given by Equation (54).

$$\frac{h}{Q} < \frac{F_0 + \Delta F_{2\max\alpha} - \bar{c}}{\Delta F_{2\max\alpha} + \frac{\Delta F_{1\max\alpha}}{1+r}k} \tag{54}$$

As shown above, the level of the financing costs (*k*) moderates the measure of over- and underhedges also. If *k* goes up, the lower bound increases, while the upper bound decreases.

If financing is not only costly, but it has a limit also, it has to be considered in the decision about the hedging ratio. The absolute constraint affects only the upper bound, as the financing need and therefore the probability of financial distress decrease with the reduction of the hedged amount. The adjusted upper bound is shown in Equation (55).

$$\frac{h}{Q} < \min\left(\frac{F_0 + \Delta F_{2\max\alpha} - \bar{c}}{\Delta F_{2\max\alpha} + \frac{\Delta F_{1\max\alpha}}{1+r}k} ; \frac{X}{Q\frac{\Delta F_{1\max\alpha}}{1+r}} \right) \tag{55}$$

Where *X* stands for the financial constraint given in absolute amount.

The effect of the absolute constraint is investigated in the next chapter by analysing the foreign exchange risk of a Hungarian exporting company.

The optimal hedge ratio is determined through Monte Carlo Simulation, using corporate specific parameters (cost function, credit spread, risk aversion) and the chosen parameters of the forward price movement process (drift and volatility). There is no limit of financing in these simulations.

I run Monte Carlo simulation in MS Excel, based on the generation of 2,000 normally distributed random variables for the price change. The initial forward rate was given, F_0=1. In order to catch the fat tail phenomena in Finance - namely the higher probability of the extreme values, than predicted by the normal distribution, - I set two extremes into the sample manually: F_1=2 and F_2=4, then F_1=2 and F_2=0. These extreme outcomes has no significant effect on the expected value, as their probability is very low (the probability of a 100% increase in the price is $1.3*10^{-11}$, based on a normal distribution with 15% standard deviation). The appearance of the extremes however excludes those hedging solutions that would cause negative corporate profit under extreme market circumstances.

Table 5 summarizes the parameters of the following simulations. The cost function is assumed to be linear; the average cost is expressed as a percentage of the initial forward rate. The extreme values of the risk aversion ratio – gamma –are set to zero (risk neutrality) and two, which is typical of the individual decision maker (Szpiro, 1986).

Parameter		**Notation**	**Figure 6**	**Figure 7**	**Figure 8**	**Figure 9**
Corporate specific	Average cost	c^*	10%	50%	10%	10%
	Credit spread	k	changing variable	changing variable	changing variable	changing variable
	Risk aversion	γ	changing variable	changing variable	2	0.5
Forward price process	Drift	μ	0	0	changing variable	changing variable
	Volatility	σ	15%	15%	15%	15%
	Initial forward rate	F_0	1	1	1	1
	Riskless return	r	5%	5%	5%	5%

Table 5: The investigated set of parameters

Source: own analysis

Figure 6 depicts the optimal hedge ratio, by choosing similar fix parameters, than Deep and Korn: the drift of the forward price is supposed to be zero, volatility of 15% and average operating cost of 10%. Because of the zero expected value of the forward position this factor has no impact to the utility function.

The results are very close to the conclusion of the Korn-model: the operating margin is high enough (90%), so that for a risk averse firm (gamma above 0.5), the utility enhancement deriving from the reduced volatility, exceeds the utility reduction of the potential financing costs of the hedge. As a consequence, 1 percentage point rise of the credit spread reduces the optimal hedging ratio by only 2.5%-point for a firm with 0.5 risk aversion coefficient.

With the fall of the sensitivity towards risks (decreasing gamma) the marginal utility of the hedge offsets less and less the effect of the financing costs. For a firm with a risk aversion factor of 0,1, the optimal hedge ratio drops to the minimum hedging level shown in Equation (10), which ensures the positivity of the profit, if the credit spread hits 7%.

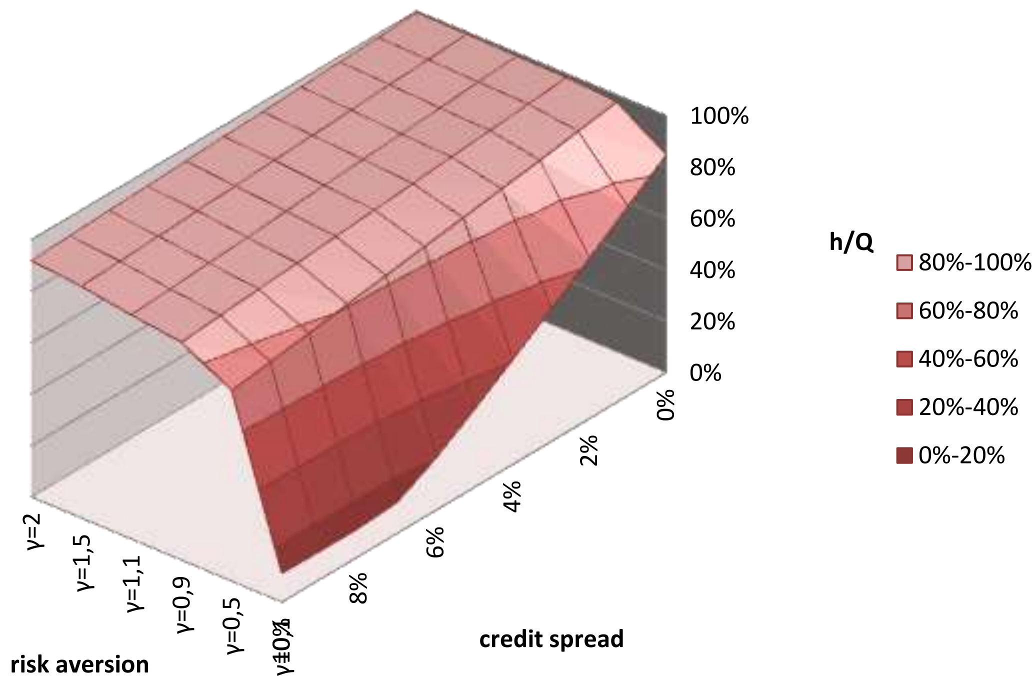


Figure 6: Optimal hedge ratio as a function of credit spread and risk aversion (forward drift: 0%, volatility: 15%, average cost 10%)
Source: own calculation

Figure 7 illustrates the optimal hedge ratio taking the same parameters than the former simulation except for the average cost, which is constant 50% here. The increase of the average cost causes a slight enhancement of the hedging ratio in each case, but through its effect on the minimal hedge ratio, the optimum is affected significantly for the less risk averse hedgers.

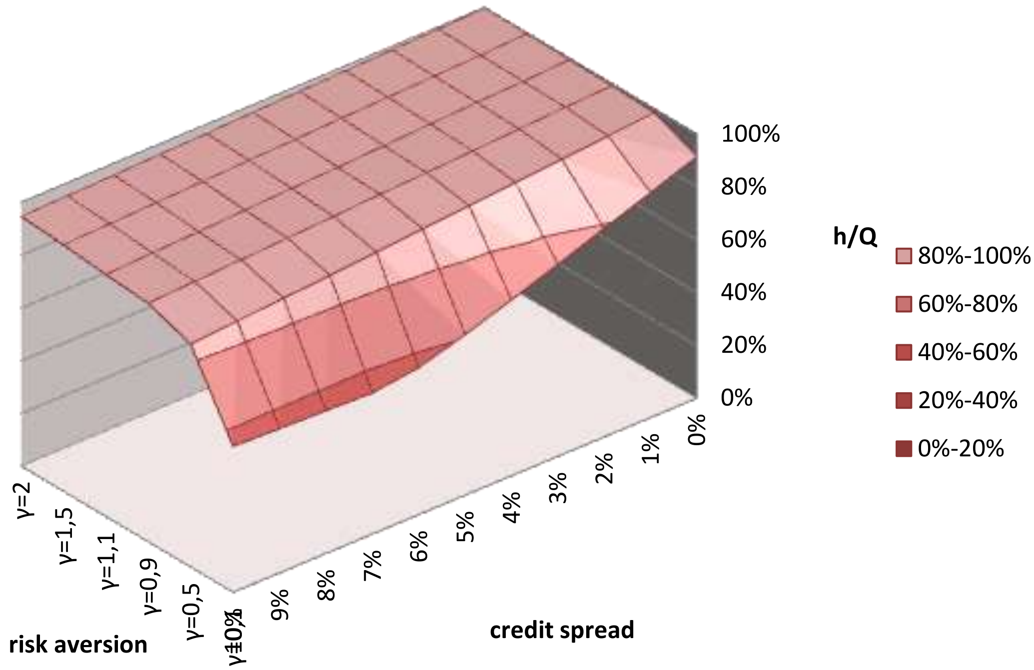


Figure 7: Optimal hedge ratio as a function of credit spread and risk aversion (forward drift: 0%, volatility: 15%, average cost 50%)
Source: own calculation

The following simulations show the effect of the non-zero drift of the forward position. Although in case of currencies, according to the uncovered interest rate parity, the expected value of the forward position is zero; it can be shown that carry trade has a significant role in financial markets.

The expected value of the hedge position takes a more significant effect on the optimal hedge ratio, than financing costs. The positive drift (μ) of the forward price causes an expected loss for a hedger in short position, that leads to a substantial reduction of the hedge ratio even for a more risk averse (γ=2) firm.

As Figure 8 shows, 1 %-point increase of the forward drift causes some 20%-point lower optimal hedge ratio. In case of negative drift – which causes the positivity of the expected value of the position – the optimal hedge ratio exceeds 100%.

A minor difference from zero drift leads to significant under- or overhedging in the optimum. Moreover the bounds of the optimal hedge ratio are reached at a 5% drift of the forward price, in our case the upper bound of 130% and the lower bound of 11% (credit spread=11%). Compared to that, the effect of the financing cost is much weaker.

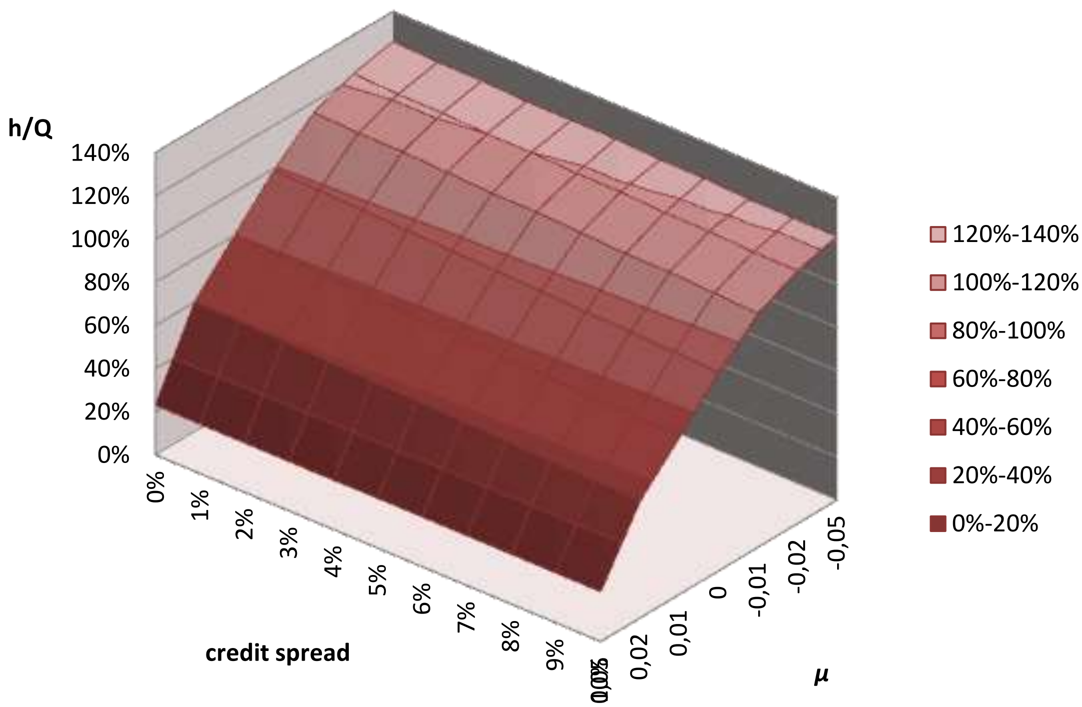


Figure 8: Optimal hedge ratio as a function of credit spread and forward drift (γ=2, volatility: 15%, average cost 10%)

Source: own calculation

With the fall of the risk aversion and so the marginal utility of variance reduction, the optimal hedge ratio converges faster to the upper or lower bound. As Figure 9 shows, 1% positive (negative) drift of the forward price is enough to shift the optimal hedging level to the minimum (maximum) quantity, if the risk aversion factor is 0.5.

If the expected value of the forward hedge exceeds 1%, the financing cost affects the optimal hedging only by its effect on the minimum/maximum hedging ratio.

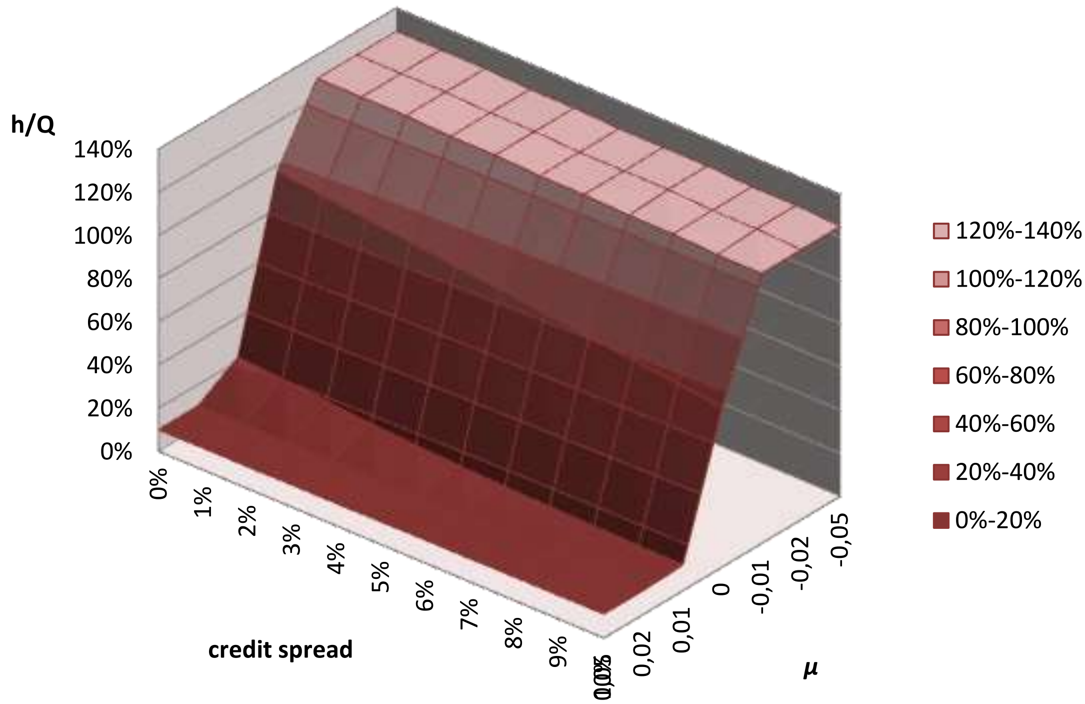


Figure 9: Optimal hedge ratio as a function of credit spread and forward drift (γ=0.5, volatility: 15%, average cost 10%)

Source: own calculation

The above simulations assumed, that the firm is able to get financing at a given cost. Under this assumption the funding liquidity risk reduces the optimal hedge ratio through the reduced profit, but this effect is moderate compared to the impact of the expected value of the hedging position or the risk aversion.

4.2 The effect of increasing financing costs

The assumption of unlimitedly available financing is not realistic in the practice. The unrealised loss of the derivative positions burdens the bank limits, so the firm can access to further financing at an enhanced credit spread.

As we could experience during the crisis, the change of the global risk aversion can cause a dramatic rise of the risk premium or even dry up financial markets by abolishing the liquidity.

The model is modified in this subchapter by allowing the credit spread (*k*) to change in the function of the forward rate in time 1.

$$k = -p * \frac{h}{Q} \min(0; F_0 - F_1) \tag{56}$$

Where *p* is a positive constant, making the credit spread to grow linearly with the extent of the credit needed to collateralize the hedge position.

As Figure 10 depicts, the effect of the liquidity risk on the optimal hedging is much more significant if financing becomes more costly.

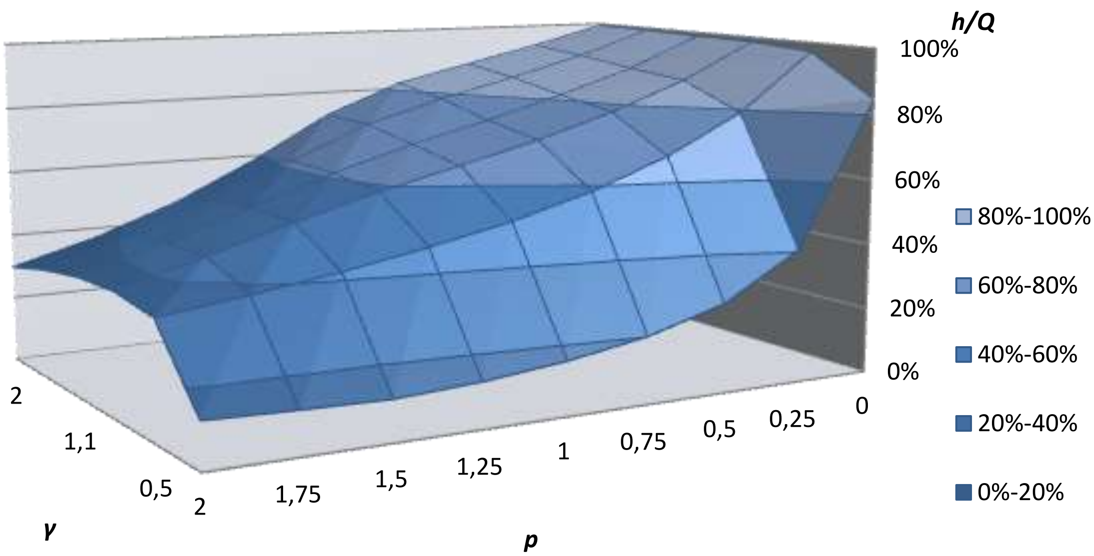


Figure 10: The optimal hedge ratio as a function of the risk aversion and the increasing credit spread (volatility: 15%, average cost 10%, forward drift 0%)

Source: own calculation

As the higher hedge ratio increases the financing cost not only because of the enhanced amount to be financed, but through the enlarged expected value of the credit spread, the optimal hedge ratio decreases essentially even in case of higher risk aversion (higher gamma), compared to the results shown in Figure 6, where the fall of the hedged amount occurred only if the firm was less sensitive toward the variance of the profit.

The value of *p* and *k* are not comparable directly, but the average credit spread is 3 percentage-points, if *p* equals to 0.5; and at a *p* of 2, the credit spread reaches 12%. Figure 11 shows the optimal hedge ratio in two cases: at a constant 3% credit spread and at a stochastic (according to Equation (56)) credit spread with an expected value of 3%.

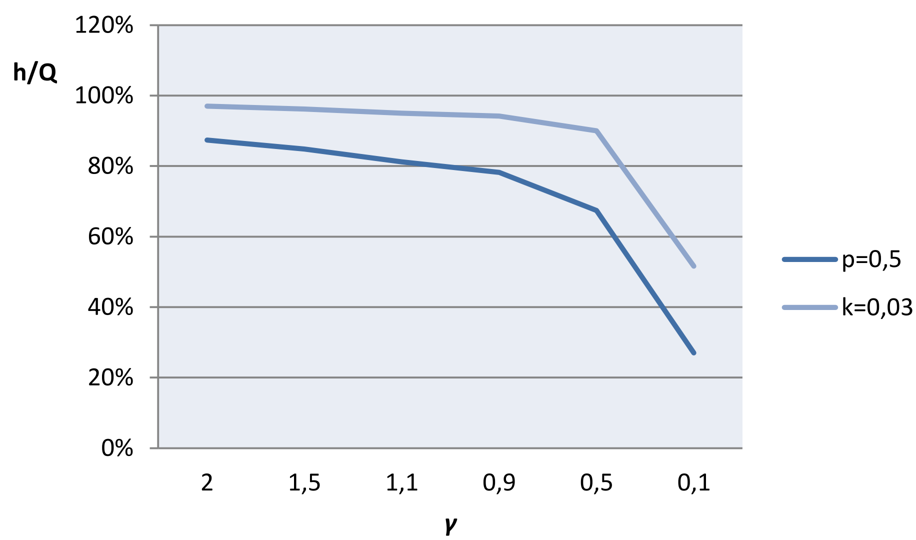


Figure 11: The optimal hedge ratio as a function of the risk aversion (volatility: 15%, average cost 10%, forward drift 0%)

Source: own calculation

The underhedge caused by liquidity risk increases with the decreasing corporate risk aversion (decreasing gamma); as the fall of the profit is less compensated by the utility enhancement of the variance reduction. The increasing financing costs however cause a further 10-25 percentage point drop of the hedging ratio (see Figure 12).

The expected value of the hedging position has an important role, even in case of increasing financing costs, but whereas in case of constant credit spread (shown in Figure 9) an expected value of 1% caused the optimal hedging ratio to reach the upper/lower bound, the increasing credit spread leads to substantial underhedge.

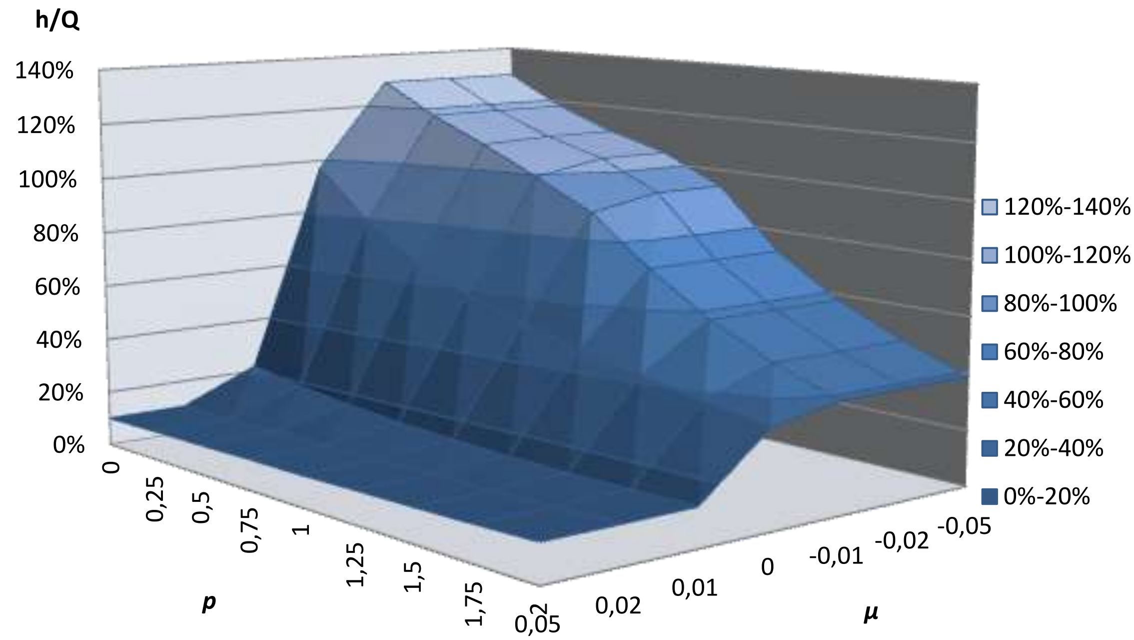


Figure 12: The optimal hedge ratio as a function of the increasing credit spread and the forward drift (volatility: 15%, average cost: 10%, γ=0.5)

Source: own calculation

This chapter modelled the optimal hedge ratio of a single risk factor in the function of the corporate risk aversion, the expected value of the hedging position and the financing cost, by maximizing the utility of the profit at maturity. The effect of the expected value of the hedge proved to be more important, than the financing (liquidity) cost of the constant credit spread. However if the financing cost is not constant, but increases with the financing need, the impact of financing become more determining.

5 MODELLING FOREIGN EXCHANGE HEDGING STRATEGIES

The aim of this chapter is to establish a framework suitable for solving practical problems by moderating the conditions of the previous model. That needs, on the one hand, a *more accurate modelling* of the risk factor, the exchange rate, and on the other hand, a *multiperiod* extension of the model. The liquidity risk is represented not only by the financing cost (credit spread) *but the available financing is limited*. As a consequence of the above, risk management cannot always provide a perfect optimum, only the best solution with a specific (sufficiently high) probability.

In practice, company operations cannot be reduced to one or two periods; the annual profit of the company is the balance of the incoming and outgoing cash flow occurring at various times during the business year. Firm value, on the other hand, includes all future – uncertain - company profits (free cash flow). Therefore, corporate risk management theoretically has to take into account all risk factors that can arise during the lifetime of the company, affecting the cash flow, and each other as well. As it appeared in the already presented theories (as well as in the model of Froot et al (1993)), the market risk factors are often linked with other factors affecting production (for example, depreciation of the exchange rate is often attended by a drop of the tradable volume of the export market); therefore, in addition to the correlation among various market risk factors, their covariance with other risks affecting operation should also be examined.

However, the present thesis discusses *only the hedging of market risks with financial derivatives, and considers the investment and financing decisions of the company as given*. The long-term hedging of market risks, as Flesch (2008) points out, is not feasible through financial derivatives, partly because in many cases the appropriate instruments are not available (beyond a certain maturity), and partly because the expenses and risks incurred by the long-term hedging outweigh the benefits of hedging. For this reason, I include long-term market risks with strategic risks, thus their management belongs to the strategic decisions of the company (long-term presence in a foreign market, withdrawal, etc.).

However, the market of short-term (within 1-2 years) derivatives is highly liquid in case of most financial products (such as exchange rates), and the range of instruments available in the market is sufficiently wide; consequently, taking short-term foreign exchange risk can be considered an idiosyncratic risk. Since the subject of the analysis is the optimal management of short-term market risks, I am going to consider the produced quantity (exposure) as given.

Among market risks, the risk arising from foreign exchange rate fluctuations affects most of the companies, either directly due to the export-import activities, or because of foreign currency funding. The *natural hedge* - matching of cash flows arising in different foreign currencies, (e.g. loans taken in the currency of the export revenue), - is a fundamental way to manage foreign exchange risk. The financial derivatives can be used to manage the remaining exposure. The foreign exchange market, with an average daily turnover of USD 5,300 billion (BIS, 2013), is the most liquid market in the world; under normal circumstances it can be called an almost perfect market. In this market, it is unlikely that a non-financial enterprise has comparative advantage in trading with any of the convertible currencies; therefore, in this case, the goal of risk management should be the reduction of risk.

Changes in the interest rate influence not only the direct credit cost of the company, but through their effect on the forward rate, the hedging price too and they have an impact on the value and the potential financing need of the hedge position as well. In practice, companies typically enter into interest rate hedging transactions only if it is required by the financing bank or it is included in the conditions of the credit[43]. This phenomenon is in part explained by the fact that in case of a rising yield curve, fixing interest rate level in the first periods incurs additional expenses for the company; moreover, not every company is able to undertake the associated transaction costs. Therefore, the risk management of the borrowing costs is more likely to be performed when establishing the loan conditions.

In the previous chapter, the financing cost (credit spread) constituted the (funding) liquidity risk, the discussed model assumed that the company will always be able to get financing for a certain spread. In practice, the financial sourcing is often not feasible in the short term; therefore, *the most important task of risk management is to ensure a minimum level of company cash flow.*

[43] This statement is also investigated by the empirical research.

The aim of the present chapter is *to determine the optimal hedging strategy of the position exposed to foreign exchange risk*, by comparing the results obtained with several hedging instruments appearing as alternatives to reducing the hedging ratio. I examine whether financial engineering can be justified by liquidity considerations, and whether it is reasonable for companies to apply hedging strategies other than the simple forward position. Unlike in the previous chapter, evaluation is not carried out on the basis of the expected utility of the profit realised in a given point of time, instead by examining the total cash flow of the position, I compare first the hedging of the risky revenue due in a single maturity, then the hedging of revenues occurring at regular intervals in the course of a year. Here, the choice between cash-flow distributions arising as a result of specific strategies is made taking into account a liquidity constraint determined by different (as described in subsection 3) risk metrics. The source of the risk is the exchange rate; revenue is generated in foreign currency (Euro), while the domestic currency is the Hungarian Forint. So the EUR/HUF exchange rate needs to be modelled and forecasted as accurately as possible. The next subsection describes the methods of exchange rate modelling; afterwards, I model the EUR/HUF exchange rate, the results of which will be used for further simulations.

5.1 Modelling market prices

According to the *efficient market hypothesis* (Fama, 1970), the prices on the market reflect all information[44], so the change of the price is due to the randomly incoming new information. Therefore the random variable to be modelled is the (logarithmic) change of the price, the (log) return.

The models introduced in the following contain no mean-reversion, as the interest rate models does.[45]

Theoretical models, - for example the Black-Scholes-Merton model (Black and Scholes, 1973) applied for the pricing of derivatives, or the models of Deep and Korn, presented in chapter three – often assume, that the price follows *geometrian Brownian motion*, described

[44] Depending to the type of information (past, public, or even insider information) weak, semi-strong and strong form of market efficiency can be distinguished.
[45] Interest rate models are detailed in Puhle (2007).

by Equation (31). In that case, based on the stochastic analysis, the logarithmic change of the price – logreturn (y_t)[46] - follows arithmetical Brownian motion:

$$y_t = mdt + \sigma dw_t \tag{57}$$

So the return of the period *dt* has two parts, one is deterministic and proportional to the time, the second is random and normally distributed. Consequently the logreturn is a normally distributed random variable with a constant expected value of *m*, and standard deviation of *σ*.

The above model is to be generalized in three directions (Bos et al, 2000): firstly, the drift can be a stochastic and/or autoregressive process, secondly the volatility can change over time, and thirdly the normality of the stochastic part can also be lifted.

In general form:

$$y_t = m_t + \varepsilon_t, \qquad \varepsilon_t \approx i.i.d.(0, \sigma^2_{\varepsilon,t}) \tag{58}$$

$$m_t = \rho m_{t-1} + \eta_t \qquad \eta_t \approx N(0, \sigma^2_\eta) \tag{59}$$

In the specific case of ρ=1 and η_t=0, the white noise process of Equation (57) is given.

Two, from risk management perspective very important facts of market returns are the phenomena of *fait tails* and the *volatility clustering*. The former refers to the fact, that the probability of extreme outcomes on both sides is higher than predicted by the normal distribution, the latter is the phenomenon that huge changes in the price are often followed by huge (in any direction) price movements, after a quiet day insignificant changes are expected. These empirical facts can be explained in the models containing stochastic variance.

Based on the work of Engle (1982), Bollersev (1986) formalized the model of *general autoregressive conditional heteroscedasticity*, (*GARCH*), which models the volatility in the function of the volatility of the previous period.[47].

[46] The logreturn, y_t, is the change of the cumulated logreturn Y_t in the period of *dt*: $y_t=dY_t$.

The stochastic term of Equation (58) in the GARCH(*p*,*q*) model is the following:

$$\varepsilon_t = \sigma_t z_t \qquad z_t \approx N(0,1) \tag{60}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \ldots + \beta_p \sigma_{t-p}^2 \tag{61}$$

GARCH models offer a good explanation for the heteroscedasticity of the real return, and as in the consequence of the stochastic volatility, the probability of extreme events increases, the distribution is fait-tailed, even if ε_t terms are normally distributed.

If the distribution remains leptokurtic even after the correction with the stochastic volatility (*conditional fat tail*), the distribution of the stochastic term differs from normal (Tulassay, 2009). In that case, most models use *Student-t* distribution, which means in the framework of a GARCH model, that variable z_t in the Equation (60) is to be replaced by a *t-distributed* variable with zero mean and standard deviation of 1 and its degree of freedom is also to be estimated.

5.2 *Simulation of EUR/HUF exchange rate*

For describing the development of the exchange rate, I choose the time interval between January 2006 and August 2012 as a reference time period, as these more than 6.5 years include the quiet pre-crisis period, the beginning of the financial crisis, as well as the development of the current economic and debt crisis. The analysed data consists of the daily logarithmic returns calculated from the daily average exchange rates of the NBH (National Bank of Hungary) in the above time period[48].

Figure 13 shows the autocorrelation of the daily logreturns and squared logreturns for various lags. It is visible that, the first-order autocorrelation of logreturns is significant at 95% level, and the squared logreturns are significantly autocorrelated for multiple lags; therefore, the time series is autocorrelated and it contains ARCH effects. First, I estimated

[47] Other models of stochastic volatility are described in Jacquier et al. (2002).

[48] That is, the chain indices of the exchange rate's logarithm. The return on holding foreign exchange currency is different; it includes the interest of the foreign currency deposit, too.

the GARCH(1,1) model with first-order autocorrelated expected value, but since the autoregressive member of the expected value equation did not prove to be significant, I omitted this effect, so the model corresponds with the temporal independence described by the efficient market hypothesis.

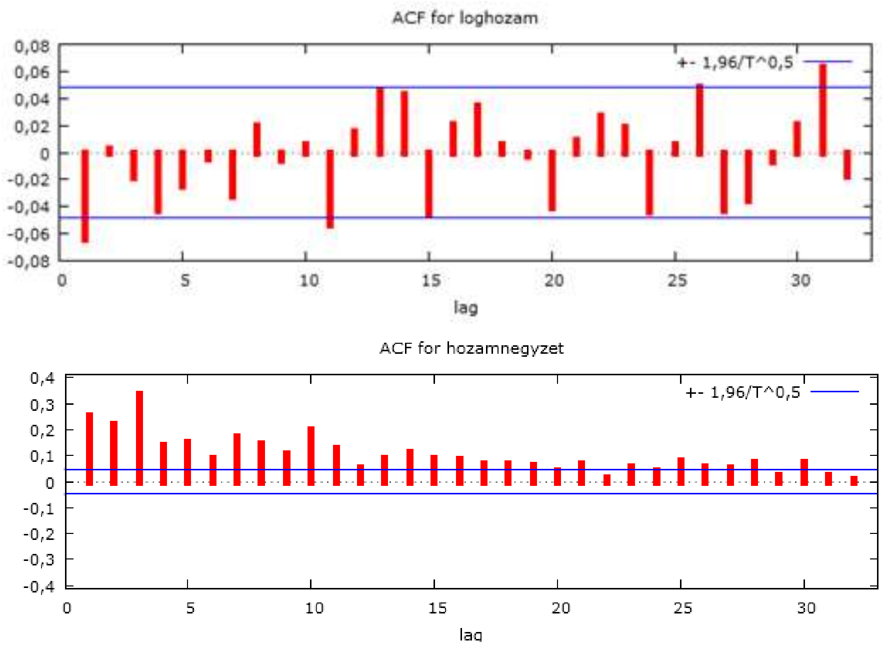


Figure 13: Correlogram of the daily logreturns (upper) and the squares of logreturns (lower) of EUR/HUF between 2006 – 2012

Source: own calculation in Gretl.

The variance equation parameters of the GARCH(1,1) model are significant (Table 6), and the unconditional variance turned out to be finite. Although the constant also proved to be significant, its value is almost zero. Though the residuals remained slightly fat tailed, the estimation with *Student-t* distributed variables resulted in so extreme price fluctuations (the exchange rate reached the 80,000 EUR/HUF level within a year), which are not feasible under normal market conditions. For this reason, I used normally distributed variables for the simulation.

Parameter	*coefficient*	*Standard deviation*	*z*	*p-value*
Expected value equation				
constant	0.000029	0.00014442	0.204	0.83831
Variance-equation				
alpha(0)	0.000002	4.16E-07	3.65	0.00026
alpha(1)	0.133741	0.0197286	6.7791	<0.00001
beta(1)	0.84548	0.0212266	39.8311	<0.00001

Table 6: Estimated parameters of GARCH(1,1) model based on the EUR/HUF daily logreturns in the period 2006-2012

Source: own calculation in Gretl.

The constant in the expected value equation is not significantly different from zero; therefore, the expected change in the EUR/HUF exchange rate is zero.

In case of the foreign exchange rates, the forward exchange rate can be calculated based on the covered interest rate parity; Equation 2 of Chapter 1 is modified so that the convenience yield is the risk-free interest rate (*rf*) of the foreign currency.

$$F_{t,T} = S_t e^{(r_{t,T} - rf_{t,T})*(T-t)} \tag{62}$$

The difference of the forint- and the euro interest rates ($r_{t,T}$-$rf_{t,T}$) in the last decade varied between 3 and 8 percentage points (see: bottom diagram in Annex III); therefore, the forward exchange rate was higher than the spot exchange rate and also the expected spot exchange rate at maturity ($E[S_T] < F_T$) since the systemic risk of the Euro is negative (Hull, 1999), meaning it moves usually in the opposite direction as the Hungarian market portfolio. Consequently, the drift of the forward exchange rate is negative, so the forward sale of the foreign currency has a significant, positive expected value (equal to the interest rate differential).

5.3 Risk management objectives, risk measures

The aim of the risk management in Chapters 3-4 was to maximize the utility of company profits (realised in a single maturity). There, the preference concerning the distribution of the profit appeared in the utility function of the company, and the distribution was optimised by the hedging derivative position. Assuming limited funding sources, the risk management needs to take additional constraints into account, which ensure the minimum level of cash-flow prior to maturity. The risk is quantified through risk measures that the risk management applies to.

Because risk arises from the diversity of possible outcomes, the most evident indicator of the measurement is the *standard deviation* as mentioned above. Standard deviation will give sufficient information about distribution, provided it is symmetric, and the probability of extreme outcomes is adequately low, as in the case of normal distribution, for instance. If this is not the case, the higher-order moments are also necessary for the description of the probability distribution. *Skewness* shows in what direction can outcomes greatly different from the expected value appear; if it has a negative value, large negative surprises have a higher probability[49]. *Kurtosis* refers to the thickness of the tails; its value is 3 in case of normal distribution; a higher value indicates that the probability of the occurrence of extreme outcomes is higher than in the case of normal distribution.

Both standard deviation and kurtosis take into account the deviation from the expected value in both directions[50], while the objective of risk management is to keep the negative outcomes under control.

An indicator for measuring *downside risk* is *semi-variance*, which shows the average deviation from the average of the below average outcomes. In case of discrete distribution, the semi-variance of random variable x is:

$$semi\,\mathrm{var} = \sum_{i=1}^{k} p_i \max[\,0;(E(x)-x_i)]^2 \tag{63}$$

Where k is the number of all possible outcomes, p_i denotes the probability of each outcome, and $E(x)$ the expected value.

[49] Annex VI contains the formula for calculating the mentioned dispersion indicators.
[50] Additional symmetric risk measures are absolute deviation from average, and Gini's mean difference, for these see Bugár, Uzsoki (2006).

In case of continuous distribution:

$$semi\,\mathrm{var} = \int_{-\infty}^{E(x)} (x - E(x))^2 f(x)dx \tag{64}$$

Where *f(x)* is the density function of *x*.

Risk can be calculated not only with the dispersion of values below average, but for any outcomes under the set target value, semi-variance being only a special case of it. The *below-target risk*[51] indicator, published by Roy (1952), was applied for measuring performance by Sortino (1991) under the name *downside risk*, *DR*, which can be calculated as the average of the squared difference below a specified threshold (*t*):

$$DR = \int_{-\infty}^{t} (t - x)^2 f(x)dx \tag{65}$$

The generalisation of the downside risk measures is the *Lower Partial Momentum*, which can be applied with any risk attitude (*a*) and threshold number (*t*) (Bawa, 1975):

$$LPM = \int_{-\infty}^{t} (t - x)^a f(x)dx \tag{66}$$

If *a*=0, the indicator shows the occurrence probability of an event below the threshold, such risk measure is characteristic of risk-loving investors; a=1 is the risk measure adequate for risk-neutral investors. The above mentioned below-target risk indicator arises if *a*=2, and it is characteristic of risk-averse investors.

Value-at-Risk, VaR, was taken over as a risk measure by the already mentioned bank regulatory provisions, based on Basel recommendations, from the banking practices of the '90s. Value-at-Risk is the maximum loss (*l*) expressed in cash value (or percentage) that the

[51] Markowitz had already recognized the benefits of semi-variance as opposed to variance but discarded its use due to calculation difficulties (Nawrocki 1999).

investor can suffer on the given asset, with a specified probability (α), during a specified period of time (t), assuming normal market conditions (Jorion, 1999):

$$VaR_{\alpha,t} = \inf\{l \in R : P(x > l) \leq 1 - \alpha\} \qquad (67)$$

Where x stands for the amount of loss. Because VaR is easy to interpret, it became the dominant measure of the risk management practice; however VaR provides no information about the losses occurring in 1-α percent of the cases. The other disadvantage of VaR is that this risk measure is not coherent. The concept of coherent risk measures was defined by Artzner et al. (1999), according to the following: a risk measure is coherent if it satisfies the following 4 properties:

- Monotonicity: if a portfolio always suffers at least the same amount as the other portfolio, then the risk of the first portfolio should be equal or higher than the risk of the second portfolio.
- Positive homogeneity: multiplying a portfolio with a positive constant, the risk of the portfolio should be also multiplied by the same constant.
- Translation invariance: giving a certain amount of cash to the portfolio, the risk of the portfolio should be reduced by that amount.
- Subadditivity: it is the diversification principle, adding two portfolios together the risk of the joint portfolio should be less, than the sum of the original risks.

VaR satisfies this latest property only if the distribution of the loss is elliptical; in other cases (asymmetrical or fat-tailed distributions) Value-at-Risk of the joint portfolio can turn to be higher than the sum of the VaR-values of the separate portfolios, meaning a negative diversification effect. Examples and the regulation difficulties deriving from the lack of subadditivity are presented in Csóka (2003). Value-at-Risk is a certain quantile of the loss distribution, while a much more adequate measure can be the expected value of the losses exceeding a given level.

Artzner et al. (1999) suggest such a risk measure the *tail conditional expectation (TCE):*

$$TCE_\alpha(x) = E\left[\frac{x}{r}\middle|\frac{x}{r} \le -VaR_\alpha(x)\right] \tag{68}$$

Where *r* is the discount factor. Other names of the above measure are *conditional Value-at-Risk* (CVaR), or *Expected Shortfall* (ES). If the loss distribution is continuous the calculation of this measure is unambiguous, but in case of discrete distribution the probability of the threshold value can differ from zero, so allowing the equality can lead to a downward bias of the measure. In order to get around this shortcoming, Acerbi and Tasche (2002) define Expected Shortfall according to the following and they also prove its coherency:

$$ES_q(x) = -\frac{1}{q}\left(E\left[x \middle| x \le x_q\right] + x_q\left(q - P(x \le x_q)\right)\right) \tag{69}$$

Where q stands for the given worst fraction of all cases, it corresponds with ($1\text{-}\alpha$) of the former definitions and x_q denotes VaR_{1-q} of Equation (67). The second term is the correction to the conditional Value-at-Risk. If the probability of q equals to zero, this second term has a value of zero, and Expected Shortfall and CVaR are the same.

Value-at-Risk and other risk measures that correct its shortcomings were defined by the risk management of financial institutions (banks, insurance companies and investment funds). These measures quantify risk as a loss on the assets expressed in cash (value risk). The most important risk of the financial institution is the value risk, as they can meet their liquidity needs anytime from the market (under normal circumstances)[52]. Contrarily corporate risk management focuses rather on ensuring cash-flow, liquidity and the earnings.

Therefore corporate risk management uses cash-flow at risk, (CFaR) (Stein et al, 2001) and expected shortfall of the cash-flow, as risk measures instead of VaR. The former is the

[52] Although the cases in the first chapter prove that even financial institutions can face liquidity constraints.

given quantile of the future cash-flow, the latter is the expected value of the worst outcomes, the average of the cash-flow in the worst cases (with a given probability).

An important difference of VaR and CFaR-type measures is the holding period, VaR is usually calculated for shorter term (10 trading days), as financial institutions can liquidate their position within this period, while the time horizon of corporate risk management is much longer, it can be measured in years. Consequently the calculation method differs: in case of VaR the expected value of the risk factor is neglectable compared to the effect of the volatility[53], so it is considered to be zero (Duffie and Pan, 1997), however corporate risk management cannot disregard the expected drift of the risk factor.

5.4 Simulation of EUR/HUF hedging strategies

In the examined situation, the source of market risk to be hedged is the change in the EUR/HUF exchange rate; the company hedges foreign currency revenue that will become due one year later. The model of changes in foreign exchange rates used in the simulations is the GARCH(1,1) model presented and estimated in section 5.2, with a normally distributed stochastic variable (Table 6), in which the expected drift of the daily logreturn (y_t) is zero, the unconditional daily variance is 0.0000731, and the equation for conditional variance is:

$$\sigma_t^2 = 0{,}00000152 + 0{,}133741\varepsilon_{t-1}^2 + 0{,}84548\sigma_{t-1}^2 \tag{70}$$

Similarly to Chapter 4, I assume that for the unrealised loss of the derivative position (regardless of its type), the bank requires collateral from the company; however, this *obligation* applies not only in a single intermediate point of time, but monthly (at the end of each month, i.e. 11 times during the tenor). If due to an increase in the exchange rate, the value of the hedge position becomes negative, the *company takes a loan with a credit spread of k* in order to meet the obligation to collateralize the position, and the return on the

[53] The drift changes proportional with the time, while standard deviation is proportional to the square root of the time.

collateral equals to the risk-free interest rate. To determine the optimal hedge ratio, the company maximizes its utility function described by Equation (15); the degree of risk aversion (γ) is 0.5. The yield curve is supposed to be horizontal, and does not change during the maturity.

EUR/HUF spot rate	275.00
HUF interbank interest rate	7%
EUR interbank interest rate	1%
1 year forward rate	291.34
Corporate credit spread	5%
Average cost	50%

Table 7: Market rates used in the EUR/HUF simulations[54]

Table 7 summarizes the used market rates and corporate specific parameters.

5.4.1 Hedging of a single exposure

Below, I examine the hedging of Euro revenue (export sales) of a Hungarian company that will become due one year later. Under the current market circumstances and corporate specific parameters of Table 7, the simulation of 1,000 exchange rate paths resulted in an optimal hedging ratio of 207%. This overhedge – the hedge position exceeds the original exposure, which means taking a speculative position in the other direction – is due to the positive expected value of the forward hedge, deriving from the 6% difference of the Hungarian and euro interest level.

However it is interesting to examine the cash-flow volatility generated by this strategy during the lifetime of the hedge.

[54] The above rates reflect the market circumstances of August 2012.

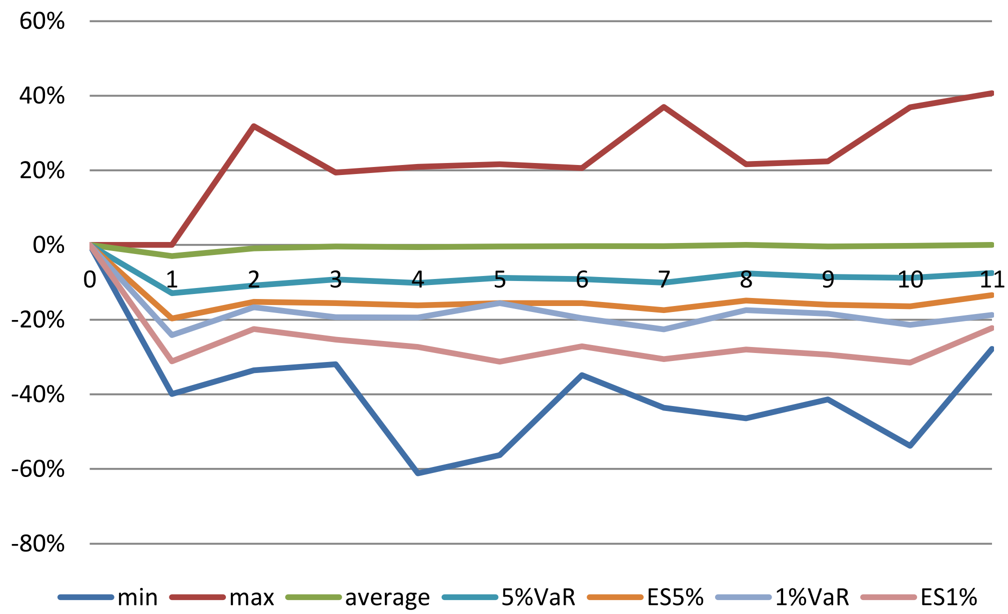


Figure 14: Measures of the cash-flow distribution of the forward hedge as a % of the exposure

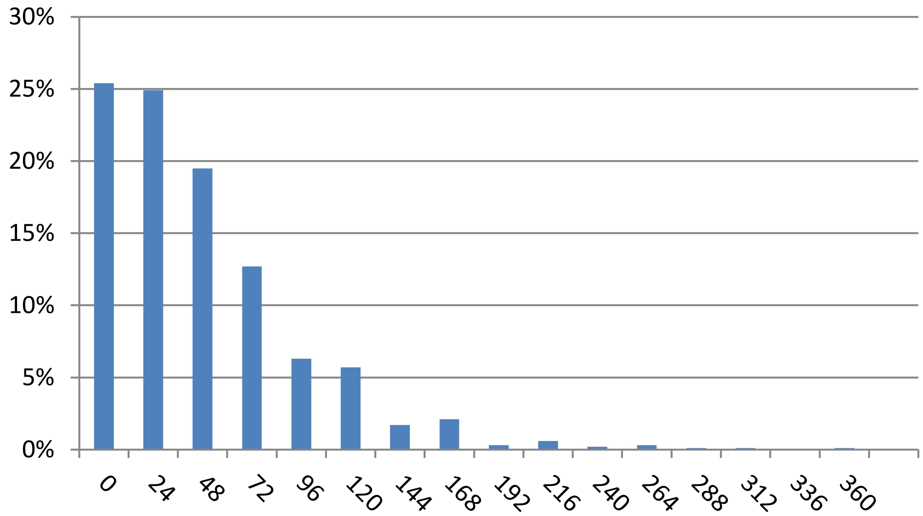
Source: Monte Carlo simulation in Excel

Figure 14 shows the cash-flow generated by the financing of the hedge position under the optimal (207%) hedging ratio in a percentage of the exposure. Each line shows a statistic featuring cash-flow distributions obtained as a result of 1000 runs. Although the average cash-flow of each point of time is around zero, in extreme cases, financing needs can reach 60% of the underlying exposure.

To assess financing needs during the hedge, I investigated the credit line (H_{MtM}) required that the company is able to maintain the position throughout the entire tenor.

$$H_{MtM} = -\min_{t=1,\dots,12}\left[\frac{F_0 - F_t}{1 + r\dfrac{12-t}{12}}, 0\right] \tag{71}$$

The distribution of the amount of credit needed for financing the optimal (207%) hedging position is shown in Figure 15. The average credit requirement is 14%; however, in 5% of the cases, financing need exceeds 45% of the exposure (5%VaR). For financing the hedging position with a probability of 99%, a credit line equivalent to 76% of the annual revenue is necessary in this example.



min	max	average	st. dev.	5%VaR	ES5%	1%VaR	ES1%
0	360	38	46	124	175	209	254
0%	131%	14%	17%	45%	64%	76%	93%

Figure 15: Credit line required financing the forward hedge as a % of the exposure (*h*=207%)

Source: Monte Carlo simulation in Excel

The above overhedge is optimal only in the absence of financing constraints. If the available financing sources are limited, the *optimal hedging ratio has also a cap*, as the reduction of the hedging ratio lowers the potential financing need of the position.

In the following simulations, I continued to look for the optimal hedging ratio, at which the expected utility is at a maximum; however, I included in the model the maximum of the credit available for financing the position as a condition limiting the liquidity risk. By doing so, we can avoid the optimization problem described by Walter (2002), namely that maximising the expected value with VaR-based restrictive conditions leads to an optimum with a very extreme payment function (casino effect). In this case, the utility function also contains preferences related to the dispersion of outcomes.

Since the maximum of the credit varies stochastically depending on the exchange rate developments, its risk is quantified by the risk measures presented in subsection 3 of this chapter. Table 8 summarizes the optimal ratio of forward hedge (forward sales) against the market and corporate specific parameters of Table 7, taking different liquidity constraints into account. In this example, the maximum credit available for financing the hedging position is 20% of the annual revenue (converted at the spot rate).

Max. credit (H_{MtM})		Credit spread (*k*)	Forward hedge	
Measure	Limit (proportional to the exposure)		Optimal hedge ratio (*h**)	Expected utility (*E*(*U*))
--	--	--	210%	25.67
--	--	5%	207%	25.59
Var(5%)	20%	5%	92%	24.70
ES(5%)	20%	5%	65%	24.41
Var(1%)	20%	5%	54,6%	24.29
ES(1%)	20%	5%	44,8%	24.18

Remark: The expected utility of unhedged position (*h*=0%) is 23.57.

Table 8: Optimal forward hedge under financing constraint

Source: Monte Carlo simulation in Excel

In case of value at risk VaR(α) indicators, the credit line ensures that the required amount to maintain the position will be met in 1-α percent of the cases. In addition, the limit specified by the expected shortfall ES(α) indicator ensures that the company meets also the average financing requirements in the worst α percent of the cases.

The optimal hedging ratio becomes lower as limitations on financing increase, which leads to a reduction of the expected utility as well, because the positive expected value of the hedge cannot be realised.

Choosing other type of derivatives for the purpose of hedging can be an alternative to reducing the hedging ratio. The cost of the hedge is deterministic if the firm buys (euro put) options[55], and being in long position, the hedge has no further financing need.

Table 9 summarizes the optimum that can be achieved in case of alternative hedging strategies. The examined *option hedging* means buying an option with a strike equal to the forward rate (forward at-the-money). The volatility used to calculate the option price is the unconditional volatility of the GARCH model (13.52%).

Max. credit (H_{MtM})		Credit spread (*k*)	Option hedge (ATM)		Collar hedge	
Measure	Limit (proportional to the exposure)		Optimal hedge ratio (*h**)	Expected utility (*E*(*U*))	Optimal hedge ratio (*h**)	Expected utility (*E*(*U*))
--	--	--	599%	25.49	246%	25.31
--	--	5%	527%	25.14	239%	25.17
Var(5%)	20%	5%	383%	25.04	144%	24.71
ES(5%)	20%	5%	383%	25.04	90%	24.34
Var(1%)	20%	5%	383%	25.04	74%	24.23
ES(1%)	20%	5%	383%	25.04	56.4%	24.09

Table 9: Optimal option and collar hedge under financing constraint

Source: Monte Carlo simulation in MS Excel.

The profit at maturity is lowered by the option fee and its financing costs (risk-free interest rate + credit spread), as if the option fee were financed from the credit.

The optimum is given if the available credit line is spent on options as a whole. In all scenarios, the expected corporate utility of the option hedge exceeds the utility of the forward hedge if financing is constrained.

The financing constraint indicates the maximum amount that can be spent by the company on buying options. Similarly to forward hedging, as the drift of the exchange rate is zero, the maximum utility is achieved by an overhedge of the position, due to the positive

[55] Annex II. contains a description of the different hedging derivatives.

interest rate difference. In the optimum, the total credit available is spent on buying options. In case of an explicit liquidity constraint, the corporate utility achieved through the option hedge exceeds the utility of the optimal forward hedging in all scenarios.

Collar[56] hedge (in banking terminology also referred to as risk reversal) is a complex option strategy, in which a EUR put option is bought and simultaneously a EUR call option is sold by the company. I chose the spot rate (275 EUR/HUF) as strike price for the purchased put option, and the strike of the call is the exchange rate (311,78 EUR/HUF) that makes the whole structure zero cost. With the collar hedge, although at a higher hedging ratio, a slightly lower (or the same) level of utility could be achieved, as by forward hedging.

The above analysis concludes that a forward hedge with an essential overhedge is optimal if financing is unlimited and cost-free, or if the financing costs are moderate. The absolute financial constraint leads to an essential reduction of the hedging ratio; none of the cases examined resulted in an overhedge. In the presence of liquidity risk option hedge is optimal, as the financing need is foreseen.

5.4.2 Hedging of multileg exposure

The risky revenue is usually generated not at a single date during the year, but steadily.

Therefore the analysis is extended to multileg strategies. The exposure – open position – is to be hedged for each month up to one year. The results are somewhat different than in the single exposure case.

In case of revenue denominated in foreign currency in the same amount on a monthly basis, the non-hedged position causes the revenue distribution per euro shown in Figure 16. The line with the checkboxes shows the initial forward exchange rates, around which the actual cash flow is dispersed.

[56] For more detailed explanation see Annex II.

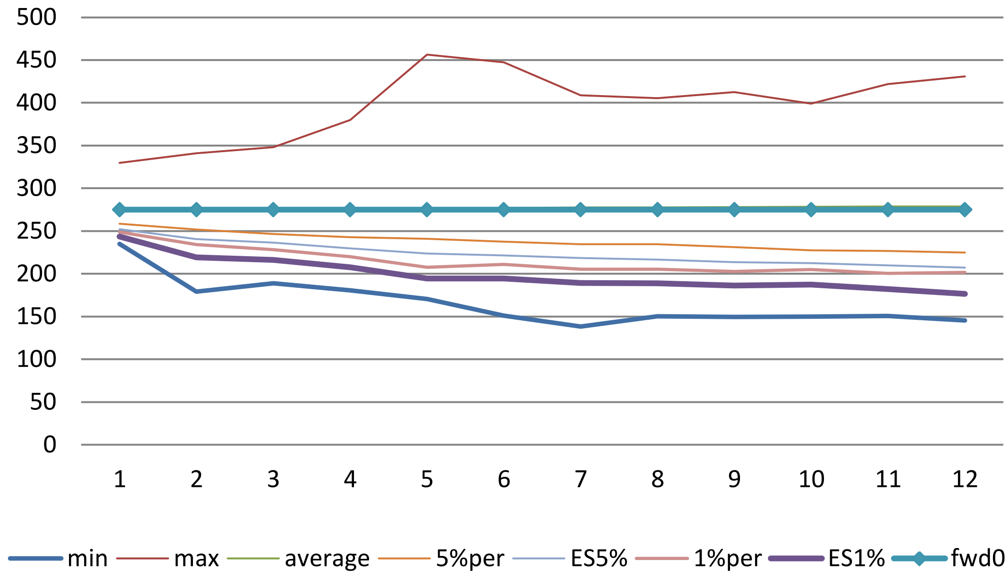


Figure 16: Unhedged monthly revenue

Source: Monte Carlo simulation in MS Excel.

The volatility of a cash flow denominated in HUF can be eliminated completely with a series of forward transactions if the mark-to market value of the hedge position does not generate any cash flow during the lifetime of the deal. If the company has to collateralize the non-realised market losses of the entire derivative exposure, the total position (euro sales revenue and hedging transactions) results in a cash-flow shown in Figure 17.

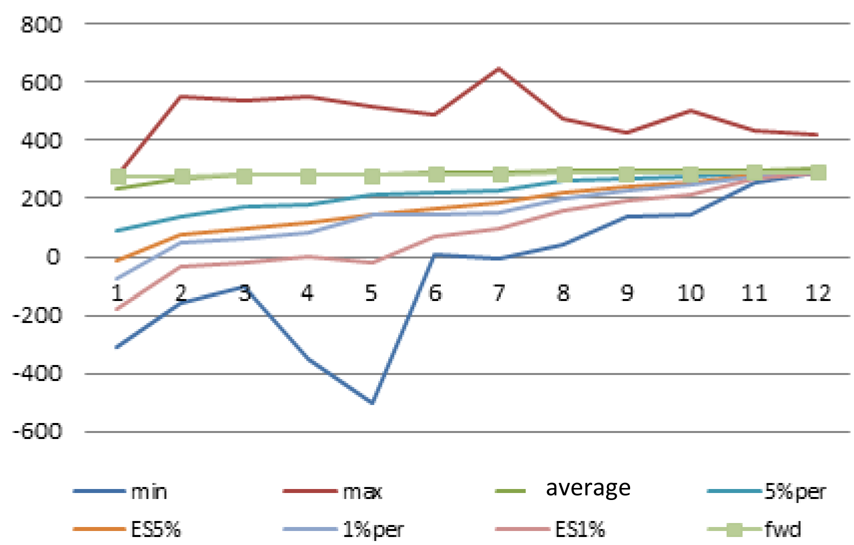


Figure 17: Cash-flow of the multistage forward hedge

Source: Monte Carlo simulation in MS Excel.

Due to the large derivative position that amounts to many times the monthly cash-flow, the monthly corporate profit (excluding operating costs) may even be negative in the first 6 months (similarly to the story of Metallgesellschaft presented in Chapter 1).

By comparing Figures 16 and 17 we can observe that although the value risk of each leg grows over time, but the exposure decreases, reducing the liquidity (cash-flow) risk.

I carried out the comparison of the hedging of annual revenue for monthly maturities on the basis of profit achieved by 5 hedging strategies. The parameters of each strategy are shown in Table 10. The series of forward transactions contains a forward exchange for each maturity, 12 altogether, with forward prices shown in column 2. In case of the average forward hedging, the exchange rates of all maturities are the same, that is, the difference between the expected spot rate and the forward rate is equal for each maturity.

Maturity (in month)	Series of forwards (Forward rates) EUR/HUF	Series of options K=F (HUF)	Average forward (forward rates) EUR/HUF	Series of collars (upper bound) EUR/HUF
1	276.37	4.28	283.78	277.81
2	277.75	6.04	283.78	280.67
3	279.11	7.38	283.78	283.59
4	280.48	8.50	283.78	286.55
5	281.85	9.47	283.78	289.55
6	283.21	10.35	283.78	292.60
7	284.57	11.15	283.78	295.69
8	285.93	11.88	283.78	298.83
9	287.28	12.56	283.78	302.00
10	288.64	13.19	283.78	305.22
11	289.99	13.79	283.78	308.48
12	291.34	14.35	283.78	311.78

Table 10: Parameters of the multistage hedging strategies

Source: own calculation

In case of option series, hedging is carried out by buying put options with strike price equal to the forward rate, the option fee of each maturity is shown in column 3. I examined two strategies based on the due date of the option fee; in the first case upfront (this is the usual market practice), but in the other case, the value increased by a company-specific interest rate is payable upon at maturity of the option.

The collar series is a series of collar transactions where the strike of the purchased put option representing the lower limit of the conversion is the current exchange rate (275 EUR/HUF), and the strike of the written call option shown in the 5th column is the level, at which the position is cost-free for each maturity. However, it should be noted that by changing the parameters, the expected value of the position, the initial costs, and the expected value of the financing needs during the tenor are also changing. The more favourable the strike is, the lower the future financing risk and the higher the expected value is; however, with initial costs are greater as well.

The maximum utility that can be achieved by the specific hedging strategies and the corresponding hedge ratios are shown in Table 11.

Hedging strategy	Credit spread (k)	Optimal hedge ratio (h^*)	Expected utility ($E(U)$)
Series of forwards	--	53%	286.58
Series of forwards	5%	53%	286.58
Series of options (upfront payment)	--	55%	283.99
Series of options (upfront payment)	5%	54%	283.92
Series of options (payment at maturity)	--	236%	290.02
Series of options (payment at maturity)	5%	235%	289.25
Average forward	--	63,4%	286.82
Average forward	5%	63%	286.81
Series of collars	--	120%	287.40
Series of collars	5%	118%	287.36

Note: The expected utility of the unhedged position (h=0%) is 282.33

Table 11: Results of different multistage hedging strategies

Source: Monte Carlo simulation in MS Excel.

I calculated the total utility by adding up the expected utility of the cash-flows of each maturity, but some sort of weighting for maturity may also be plausible. In the presented example, a higher utility can be achieved with any of the hedging strategies than without hedging. In case of multi-period hedging (as opposed to a hedging for a single maturity in the above subsection) the optimum is obtained for every strategy at a hedging ratio at which the credit line is unused, except for the option hedge, as the upfront option fee is to be financed from credit (no cash-flow is calculated for time 0.). Even in that case, the credit is redeemed at the first maturity. Accordingly, I did not examine the effect of financing constraints further.

Option hedge is optimal only if a deferred payment of the option fee is allowed. Because of the upfront financing need of the options, the option hedge has the lowest expected utility in the multiperiod hedging model.

The optimal forward hedging ratio is about 50% of the exposure, which is an essential reduction compared to the hedge for a single maturity.

The average forward construction does not significantly increase the utility compared to the plain vanilla forward transaction series but it increases the hedging ratio by about 10 percentage points.

The positive expected value of the overhedge is achieved only in the case of option and collar hedges, as the financing need of the option hedge is limited and can be foreseen. On the other hand, the strike of the sold option of the collar hedge is out-of-the-money, so the potential financing need is acceptable.

The analysis of the impact of factors influencing the utility function (variance reduction, expected value of the hedge and the financing costs of the hedge) in the example of the EUR/HUF fx-rate exposure found the optimal hedging ratio is determined by the trade-off between the huge swap-difference of the examined period and the firm-specific financial constraints.

6 EMPIRICAL RESEARCH: ANALYSIS OF CORPORATE RISK MANAGEMENT PRACTICE IN HUNGARY

The aim of the empirical research is the assessment of the market risk management practises of Hungarian companies and the comparison of the results with the conclusions of the model described. The available information about corporate risk management is limited, considering that companies have no recording or reporting obligation in this regard. The explanation of financial profit in the appendices of annual financial statements may contain guidance about the company’s financial transactions aiming to manage financial risk. This practice will change in the year of the submission of the thesis, as a consequence of the already mentioned European regulation (EMIR, 2012) that enacts the reporting of even over-the-counter derivatives.

The international literature contains several empirical analyses in connection with company or investor hedging, including Tufano (1996), Haushalter (2000), Mian (1996), Josepf and Hewins (1997), based on public databases and data from annual financial statements, or relying on the results of surveys. Dominguez and Tesar (2006) examine company exposure with aggregate data, Bodnar et al. (1998, 1999) have conducted a comprehensive survey with regard to both the set of companies and the questions examined, which analysed the risk management practices of U.S. and German companies. The questionnaire designed for the empirical research is based on these surveys among others.

In Hungary, the Central Bank conducted two questionnaire surveys in 2005 and 2007, the results of which were summarised by Katalin Bodnár (Bodnár, 2006 and Bodnár, 2009). The first survey studied the exchange rate exposure of the small and medium-sized enterprises, and the management of their exposure, concluding that the role of the sector is less dominant in foreign trade, the reason for their exposure to exchange rate risk is primarily their financing; the companies are typically indebted in foreign currencies. An important finding of the survey is that the small enterprise sector is less risk-conscious; it essentially underestimates its risk exposure, and does not manage it.

The second query included large corporations as well; this study also focused on the analysis of foreign exchange exposure, with special regard to the role of foreign currency loans, and the motivations for borrowing. The analysis concludes that most companies choose foreign currency loans due to lower interest costs, that is, in order to achieve the expected lower costs, they proactively take a speculative position. The overall results are similar to the previous ones; the Hungarian corporate sector is unaware of risk management tools, considering them expensive, complicated and ineffective.

Similar findings are made by Dominguez and Tesar (2006) when studying companies in 8 emerging markets; they explain the greater exposure of small enterprises to foreign currency risk with the limited availability of hedging instruments for this segment.

Market experience shows that the above-described findings fully apply to the small and medium-sized enterprises, but a substantial part of large companies are particularly well prepared, and have a treasury, where the on-going assessment of risks and the implementation of risk management functions take place. Thus, the Hungarian business sector cannot be considered homogeneous; the present research studies the practices of companies having developed risk management activity.

This chapter describes first the research questions; the presentation and analysis of different data is carried out in separate subsections. The summary of the results and the answers to the hypotheses are included in the seventh, final chapter.

6.1 Research problems and hypotheses

The empirical research focuses on three topics, in which framework the hypotheses below are analysed. I investigate what responses can be deducted from my own model and how the empirical data support the results of the model.

6.1.1 Risk awareness, managed risk types

After the transition, the economic environment radically changed in Hungary. In the new financial system, both interest rate- and the foreign exchange markets underwent a gradual development, and as a consequence of the currency liberalization in 2001, the Hungarian market became an integrated part of the international financial markets. The risk attitude of Hungarian companies was initially very diverse; the companies with foreign ownership adapted the practices of the parent company, and thus performed risk management more actively, while the majority of domestic enterprises have developed their own risk management practices as a result of a learning process.

An important objective of the study is examining the level of risk awareness in Hungarian corporations, and analysing what company characteristics correlate with it. The theoretical model does not examine these issues; therefore I am not going to refer to the results of the model here. Based on practical experience, companies protect themselves against exchange rate risk the most out of all market risks, using hedging derivatives; and only those companies hedge their interest rate risk, which are expressly required by the financier to do so. It is due to the liquidity premium in the yield curve in case of forint exposure, which –in accordance with the results of the model– reduces the optimal hedging ratio; while in case of foreign currency positions, the short-term additional cost caused by the rising yield curve reduces the utility growth available by hedging. Consequently, Hungarian companies are much more active in foreign exchange risk management; so the hypotheses of the next groups refer to that.

H1: Risk awareness and the size of the firm are correlated.

H2: Hungarian corporations do not hedge their positions exposed to interest rate risk.

6.1.2 Hedging method

The next set of questions concerns the actual implementation of corporate risk management, and hedging strategies. As stated by the second hypothesis, companies manage foreign currency exchange rate risk the most out of all the market risks; therefore, the issues to be examined here are related to foreign exchange hedging. The aim of the research is to assess the hedging horizon, the selected hedging instruments and the hedging ratio.

According to the experience, although forward hedging is the most common, hedging with options or structured option positions also occurs. The companies are usually sensitive about the explicit costs arising from hedging, so they prefer those solutions, which do not require an upfront payment. This was also confirmed by the simulation of EUR/HUF exchange rate risk management.

Based on the results of my model, exporting companies hedged their exposure to a greater extent in the examined period, due to the expected positive value of the forward rate. The extent of hedging depended on the selected hedging transaction.

H3: The hedging ratio of currency risk depends on the direction of the exposure; it is higher for long foreign currency positions (against HUF).

H4: The ratio of options in the hedging of foreign-exchange risk is negligible, but increasing.

H5: The hedging ratio depends on the applied derivative (forward, option).

H6: The foreign-exchange risk is hedged by derivatives in the short term.

6.1.3 Execution of hedging

The third direction of the study is whether the demand for hedging derivatives is stable over the course of the year or it depends on the market movements, as suggested by the results of the model. I examine two factors: on the one hand, the impact of market volatility, since in case of growing volatility, variance reduction achieved by hedging is higher, on the other hand, the changes in the yield gap, which affect the expected value of the forward position.

H7: The increasing volatility of the foreign exchange market increases hedging activity.

H8: Hedging activity increases with the rise of the expected value of the forward hedge position.

Data from three sources is used in the empirical analysis: statistics of foreign exchange market transactions and derivative stocks collected by the National Bank of Hungary (NBH), the time series of the foreign exchange transactions of a Hungarian commercial bank, and the results of a survey.

The data represent different levels of aggregation, which I have no opportunity to combine, as their source is different; the results obtained from the analysis of the individual databases are compared the end of the thesis.

The hypotheses related to risk awareness can be analysed only on corporate-level data; therefore, these are investigated based on the survey data. The second and third set of questions, the method and execution of hedging are examined by using both the available aggregated data, and the survey.

6.2 Analysis of foreign exchange transactions in Hungary

The National Bank of Hungary compiles the daily *turnover* and *stock* data of foreign currency transactions between domestic credit institutions and other resident partners based on the reports of commercial banks. The category of other resident partners does not clearly correspond to the business clientele, since it also includes retail transactions; however, the ratio of Hungarian companies is much more significant; therefore, in the following, I analyse these data as corporate data. Another limitation to the analysis is that hedging transactions and merely speculative transactions without any exposure cannot be distinguished; however, as the models in the previous chapters illustrated, the expected profit of the forward position can justify the transaction –entering into a speculative position that might be considered as a sort of broadly interpreted risk management–; therefore, it makes sense to analyse the overall turnover. The impact of other market data on hedging can be examined through the analysis of stock type data.

6.2.1 Analysis of Hungarian foreign exchange turnover

Turnover data broken down by transaction and currency can be downloaded from the homepage of National Bank of Hungary[57]. These data also include *day trade* transactions, and thus conclusions deriving from them are to be handled carefully; however, they visualise some important foreign market characteristics and trends (the instruments utilised or the development of transaction activity) well. Stock type data about options are not available, so the relevant hypothesis 4 is analysed on the volume data.

Figure 18 shows the average daily foreign exchange turnover since 2001, by months, broken down by transaction types, aggregated in HUF million, so including the effect of exchange rate changes. The increasing trend of turnover is clearly visible; likewise, the turnover growth and volatility increases experienced in the first months –autumn 2008– of the financial crisis in Hungary. Until May 2010, the largest part of foreign exchange turnover is comprised of spot transactions; forward turnover amounts for only about a half of that.

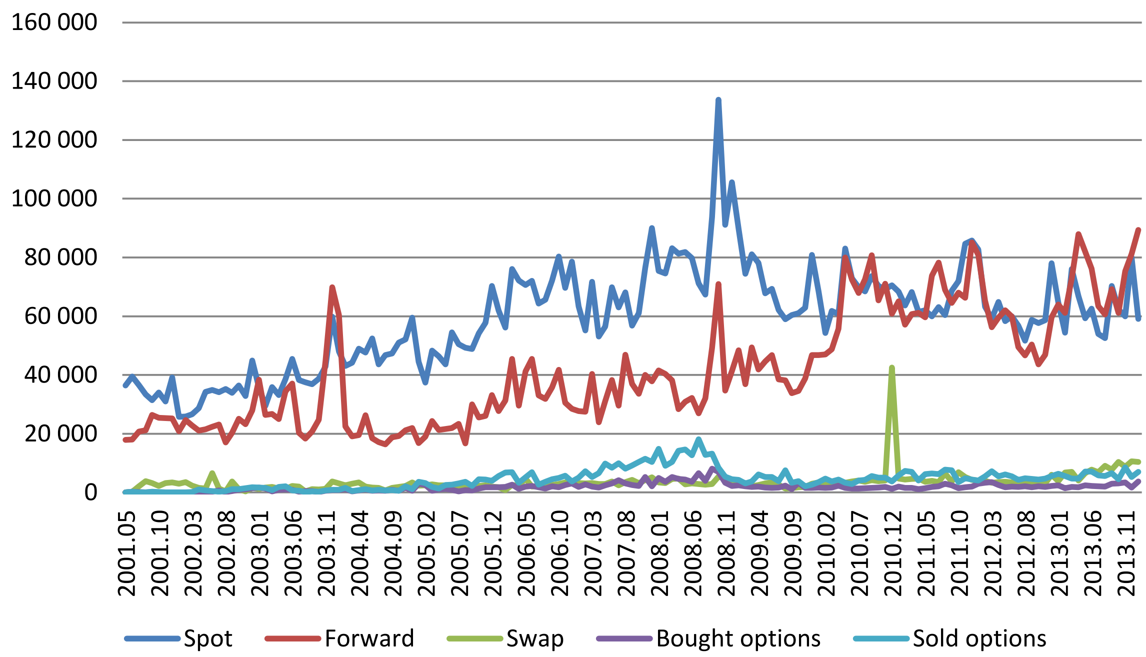


Figure 18: Daily FX-turnover of non-banking resident partners between 2001 and 2014 (HUF million)

Source: based on NBH hu0907 time series

[57] Source: http://www.mnb.hu/Root/Dokumentumtar/MNB/Statisztika/mnbhu_statisztikai_idosorok/hu0907_devforg_idosor.xls

However, in May 2010, the volume of forward turnover reaches that of the spot turnover and henceforth, it represents similar ratio of the FX-turnover.

To examine the role of option transactions, I take the data in Figure 19, which shows the proportion of option transactions bought and sold by non-bank customers within the total derivative turnover. Although the ratio of option represents only a minor portion of the total volume, but it continues to grow until the autumn of 2008, when as a result of the crisis, a strong decrease can be observed.

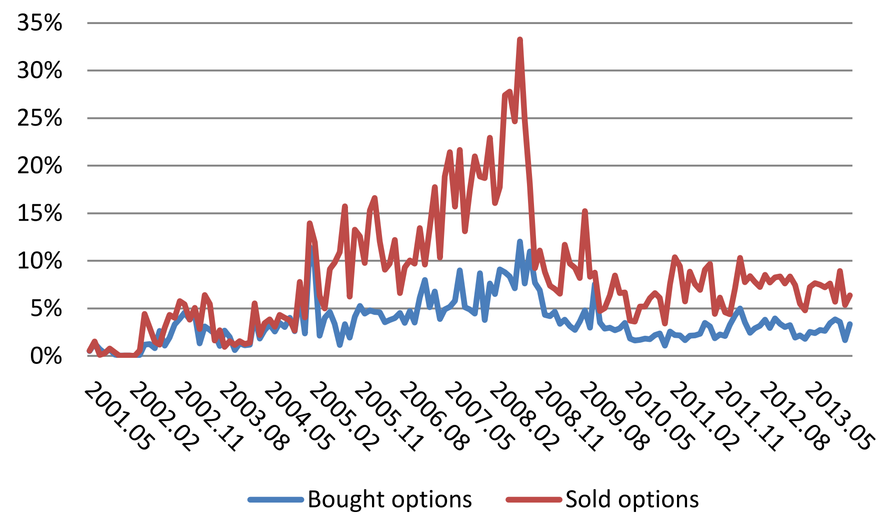


Figure 19: Daily FX-options turnover of non-banking resident partners in the ratio of the total FX volume between 2001 and 2014

Source: based on NBH hu0907 time series

In the examined period the volume of written options is typically the double of the purchased options volume. Therefore, options were used rather for speculative than for hedging purposes. The reason for this is, partly, funding liquidity, as examined in the thesis, since writing an option results in funding, and partly, the positive expected value of the written options. The written options were either part of the structured hedging solutions that aimed to tailor the position to the expectations of the clients, or simple speculations. Due to the change in exchange rate as a consequence of the crisis, significant losses were realized on these structures (for a detailed discussion see Boros and Dömötör, 2011), so most of the positions were closed, and both the banks and their customers undertake further speculative positions more carefully.

After the post-crisis decline of the options turnover the long options constitute about 2-5% of the total derivatives turnover; the ratio of short options ranges from 5 to 10%.

Table 12 shows the average of the monthly turnover of option transactions and their share within derivative transactions and also the monthly change in the period.

	Monthly turnover (MHUF)			Ratio of the monthly FX turnover		
	Mean	Change	p-value	Mean	Change	p-value
Long options	1,846	14.89	0.000	3.57%	0.007%	0.088
Short options	4,481	42.53	0.000	8.35%	0.036%	0.001

Table 12: Average and monthly change of daily FX-options turnover of non-banking resident partners between 2001 and 2014

Source: based on NBH hu0907 time series

The monthly options turnover was growing during this period both in terms of its value and proportionate share. Monthly growth rate of the volume of sold options is three times larger than the growth of the purchased option turnover. The proportion of written options in derivative transactions increased by 3.6 basis points per month, but the increase in the proportionate share of purchased options is not significant at the conventional levels of significance; the *p-value* is higher than 0.08.

On the basis of the above, it can be concluded that the increase in option turnover and the increase of proportionate share of option transactions within all derivative transactions derive from the change in the volume of written options, so it served speculative purposes rather than hedging.

The distribution of spot and forward foreign exchange turnover broken down by currency is shown in Figures 20 and 21, and Table 13 contains the average relations of the period 2001-2014.

The majority of the turnover is generated in two world currencies: euro and U.S. dollar. Hungarian foreign trade is mainly directed towards the countries of the European Union, and although it is not on the agenda at the present, accession to the Eurozone had been among the achievable goals for Hungary for a long time; therefore, most transactions are concluded in EUR/HUF. Hedging of dollar exposures is usually performed directly against HUF, but the transactions are frequently broken down into EUR/USD and EUR/HUF transactions. Transactions denominated in Swiss franc are also worth pointing out, though most of them are related to residential mortgage loans. The figure clearly shows the expansion of the Swiss franc loan portfolio until 2008, then its gradual decline due to the crisis and the subsequent regulations, and likewise, the turnover growth related to early redemption at the end of 2011.

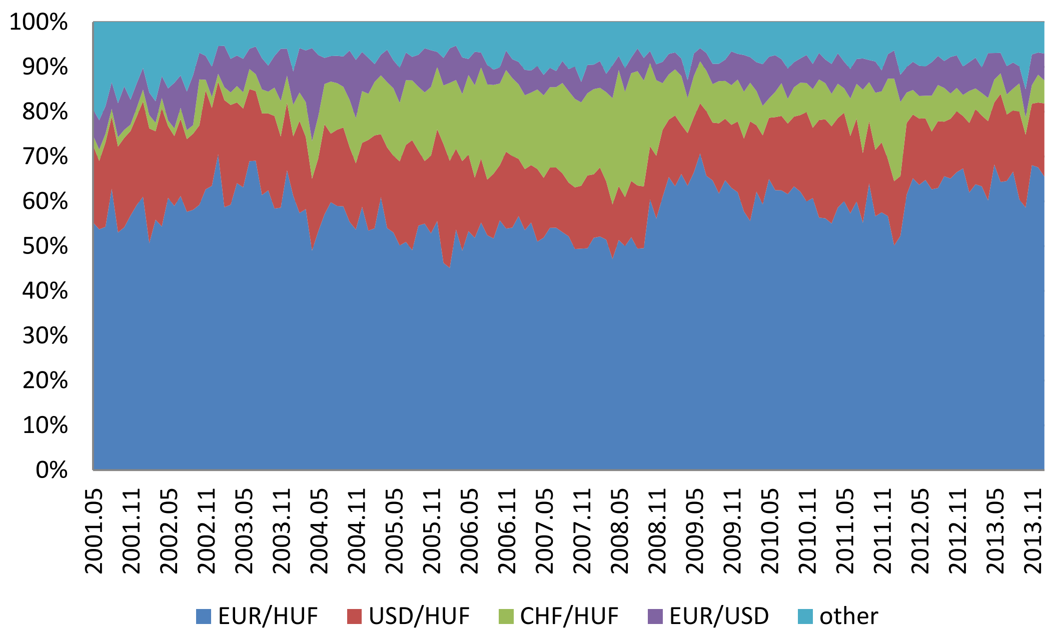


Figure 20: Daily spot FX-turnover of non-banking resident partners by currency between 2001 and 2014

Source: based on NBH hu0907 time series

The share of the different currencies in forward turnover is more volatile, but euro and U.S. dollar transactions are the dominant ones in this case as well.

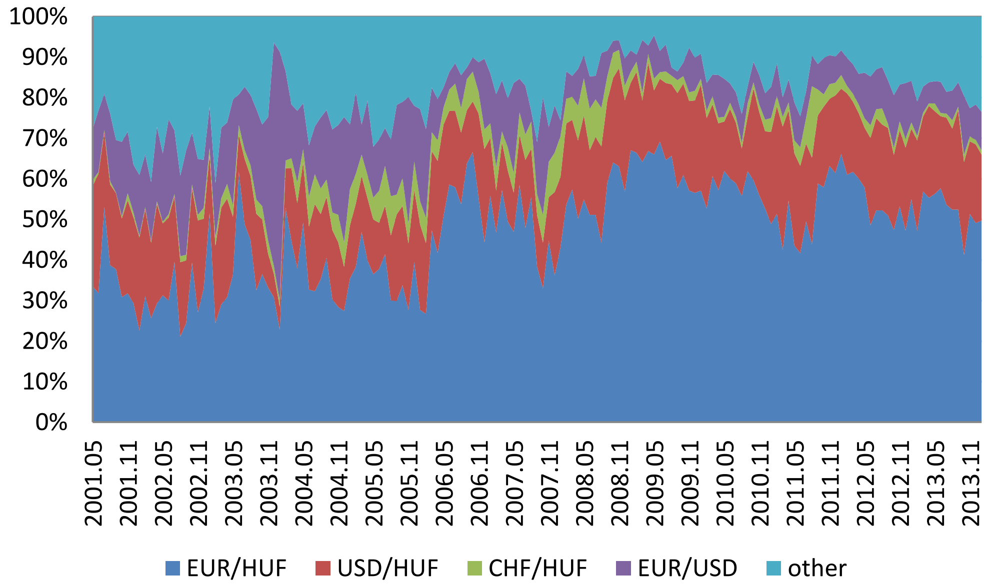


Figure 21: Daily forward FX-turnover of non-banking resident partners by currency between 2001 and 2014

Source: based on NBH hu0907 time series

In this period, euro and dollar transactions total up to 80% of the spot- and forward sales turnover.

	EUR/HUF	USD/HUF	CHF/HUF	EUR/USD	other
Spot	58.2%	16.3%	10.1%	6.3%	9.1%
Forward	47.0%	18.1%	3.7%	12.0%	19.1%

Table 13: Average spot and forward daily turnover by currency-pairs between 2001 and 2014

Source: based on NBH hu0907 time series

In case of Swiss franc transactions, the forward volume is only a third of the spot turnover, as the majority of the trades is due to the speculation for interest difference, which would vanish with forward hedging.

6.2.2 Analysis of Hungarian foreign exchange derivatives stocks

From the turnover data, we can obtain information about market activity, transaction types, and currency; however, the stock data allow for a more detailed analysis. For this purpose, the National Bank of Hungary made a database available to me that contains the daily *stocks* of forward transactions of domestic financial institutions with other resident partners in the period from January 2003 and April 2012. The database also includes the stocks' direction; thus, the development of forward long and short FX-positions can be examined separately.

Figure 22 shows that foreign currency short positions are more significant, the currency sold on forward is about the double of forward currency purchases (against HUF). This is consistent with the analysis presented in Chapter 5, which concluded that forward EUR sales against HUF has an expected positive value in the studied period; therefore, even over-hedging can be optimal, subject to the financing limits. Dominguez and Tesar (2006), by contrast, determined a higher exposure, that is, less active hedging, of exporting companies in their study of eight developed and emerging markets.

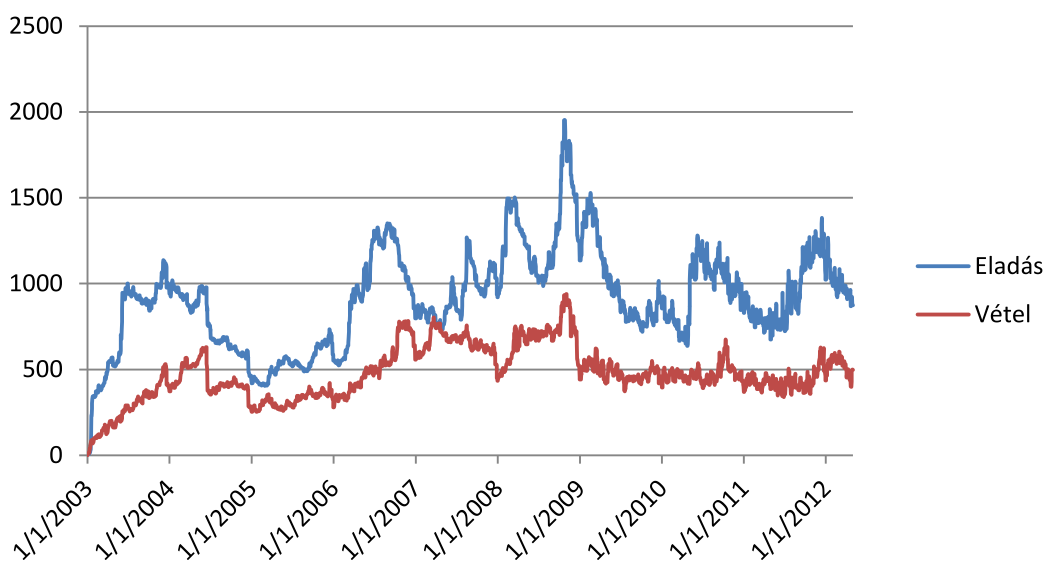


Figure 22: Daily forward stock of non-banking resident partners between 2003 and 2012 (HUF billion)

Source: NBH

Similarly, the negative expected value of forward euro purchases reduces the utility of hedging, thereby also the optimal hedging ratio.

In the following, I analyse the development of the aggregate portfolio of forward positions[58], I examine the factors that influenced the changes of long and short forward positions, and whether the conclusions drawn from the above data confirm the findings of the theoretical model of the thesis. For this, I build *a multivariate linear regression model* (a description of the method is included in Kovács, 2009), in which the dependent variable is the monthly percentage change of the stock. Because the data are provided in HUF, I converted them to EUR on the daily euro fixing in order to filter the effect of the change in exchange rate. Since not all transactions were concluded against the euro, I could not clean the data from the effect of the change in cross rate. Although the database allows for the analysis of daily data, I decided to examine monthly changes instead, due to the unsystematic effects and noises of the daily data. In doing so, I chose the first available data of each month, and assigned the percentage change to the expiration date. The study period consists of 99 months between January 2004 and April 2012. I decided to omit the data of the first year, 2003, because the data collection started then, and the scope of data collection was unstable in that period.

The open currency position to be hedged mainly derives from the foreign trade turnover, so the first set of explanatory variables are formed by the available foreign trade turnover data. The Central Statistical Office collects import and export portfolios by product groups and country groups, which are available from the website of the National Bank of Hungary, broken down by months, going back to 1996[59]. However, regarding the turnover of services, I found only quarterly data from 2009[60], which greatly reduces the size of database that can be analysed; therefore, I only included the product turnover data in the analysis.

In the theoretical model, the hedging decision is affected both by the profit achieved through hedging and by the expected value of the hedging transaction. Therefore, I included market data among the explanatory variables that can affect the risk management according to market experience and the results of the theoretical models of the study: the

[58] SPSS 20 software package was used to the analysis.
[59] Data available from: http://www.mnb.hu/Statisztika/statisztikai-adatok-informaciok/adatok-idosorok
[60] Data available from: http://www.ksh.hu/docs/hun/xstadat/xstadat_evkozi/e_qks001a.html

FX-rate, its volatility, the difference between the forward rate and the spot rate (swap difference) and the foreign and domestic interest rates.

The analysis of turnover data showed that most of the transactions are concluded against euro or dollar; therefore, I used the data series of the spot exchange rate of two *foreign exchange rates*, EURHUF and EURUSD. Considering that a change in the spot exchange rate affects also the forward rate, changes of the spot rate are expected to determine the hedging decision, as in case of an advantageous price movement, better hedging rates are available.

The next group of variables is the *volatility of FX-rates*. I downloaded the *implicit volatility* of at-the-money option with 30, 90 days or 1 year maturity for both currency pairs[61]. Based on the model, higher volatility of risk factors (foreign exchange rate) increases the utility available by hedging, and also the potential hedging needs.

As detailed in Chapter 5, the expected profit of hedging (forward) transaction is the difference of the forward exchange rate and the expected spot exchange rate, which is equal to the difference of the forward rate and the spot rate, if EURHUF exchange rate process corresponds the GARCH (1,1) model with the parameters of Table 6. This difference, called *swap-difference*, is quoted in the interbank market; its time-series is available on Bloomberg.

The swap-difference is determined by the difference of the spot exchange rate and the interest rates of the two currencies. Therefore, in addition to the one-year development of swap-difference, I included among the explanatory variables 1 year BUBOR representing HUF interest level, and 1 year EURIBOR data for the foreign interest.

In order to ensure the independence of the individual observations required by the methodology, both the dependent variable and the explanatory variables consist of the percent change in each factor.

By examining the time series of the derivative stocks (Figure 23), we find that both the buying and selling positions in general are strongly reduced between December and January.

[61] Data source: Bloomberg

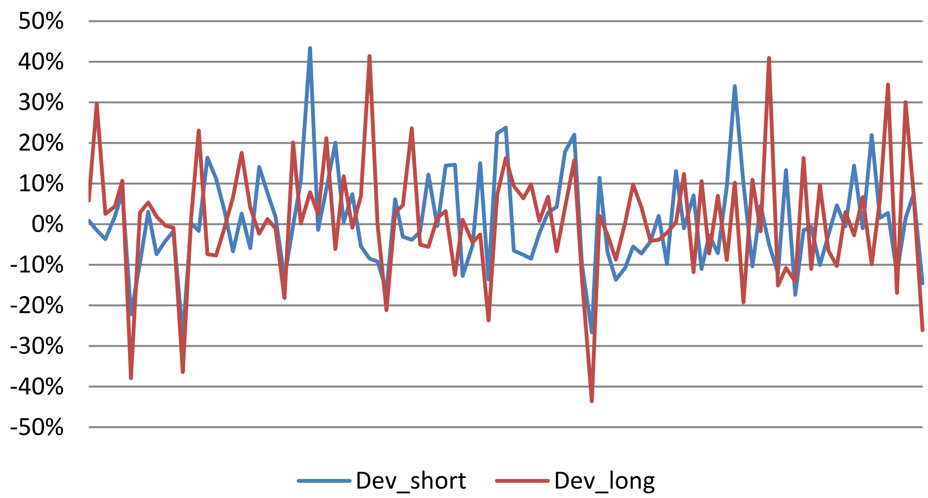


Figure 23: Monthly change of the forward stocks between 2004 and 2012

Source: NBH

This is explained by the positions expiring or closed out at the end of the year, since most corporations hedge to the reporting date, or in many cases, they do not want to report a substantial derivative portfolio in their annual statements.

Therefore, in addition to market factors, I included the "*December effect*" as a binary explanatory variable, the value of which is 1 if the date shows the change in December (from early December to early January), in any other case, it is 0.

The explanatory variables within a variable group are clearly correlated. I included more variables to quantify the same factor, in order to find the variables with the highest explanatory power. However, variables are not uncorrelated between groups of variables either; therefore, I addressed the collinearity between the explanatory by choosing the stepwise method in the regression, thus the redundant variables were not included in the model.

Table 14 contains a summary of the explanatory variables of the regression model.

Variable clusters	Variable	Short name
Foreign trade	Monthly export of goods	Export
	Monthly import of goods	Import
Market prices	EURHUF spot rate	EURHUF
	EURUSD spot rate	EURUSD
	12 month BUBOR	BUBOR
	12 month EURIBOR	EURIBOR
	12 month EURHUF swapdifference	EURHUF_swap
Market volatility	EURHUF 30 day implicit volatility	EURHUF_v_30
	EURHUF 90 day implicit volatility	EURHUF_v_90
	EURHUF 1 year implicit volatility	EURHUF_v_1y
	EURUSD 30 day implicit volatility	EURUSD_v_30
	EURUSD 90 day implicit volatility	EURUSD_v_90
	EURUSD 1 year implicit volatility	EURUSD_v_1y
December effect	The period is December	December

Table 14: Explanatory variables of the regression model

Source: own analysis

The subsections below discuss the results of linear regression models explaining the changes of short and long forward positions.

6.2.3. Modelling short forward stock positions

Since the regression constant proved to be insignificant in the first run, I queried the model without the constant[62]. The analysis of the residuals showed that only one observation, December 2009, deviated critically from that predicted by the model: the value of the standardized residual exceeded 3; therefore, I excluded this month from the analysis.

Based on the *F-statistics* of the regression model, the model is significant at any conventional level (*p-value* 0.005), the adjusted R^2 coefficient is 0.584, i.e. nearly 60% of the total variance is explained. The essence of the stepwise method is that the independent variables are included gradually, on the basis of their explanatory power, as long as the new

[62] The SPSS output tables and diagrams of the multivariate linear regression model are included in Annex VII.

explanatory variable significantly improves the model. Table 15 shows that short forward positions were affected by four factors substantially: the change of the EURHUF spot rate, the position closings in December, the 30-day implied volatility of EURHUF, and the changes in the 12-month EURIBOR. On the basis of the high *t-statistics* and low *p-values* of the table, each variable is significant at all conventional levels.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
EURHUF	2.035	.301	.475	6.763	.000	.520	.572	.441	.860	1.163
December	-.176	.029	-.395	-6.021	.000	-.407	-.528	-.392	.987	1.013
EURHUF_v_30	.104	.021	.336	4.900	.000	.488	.451	.319	.901	1.110
EURIBOR	.355	.124	.193	2.857	.005	.149	.283	.186	.927	1.078

Table 15: Linear regression model of short forward position

Source: NBH, Bloomberg data analysed in SPSS

It can be seen that the changes *changes in foreign trade turnover* has no effect on the derivative stock, which can be explained by the fact that products crossing the economic border of the country count to foreign trade, while hedging is carried out prior to the sale, in advance. In addition to the above, the hedging demand can arise by the already-mentioned *service turnover* or other clearings between resident business entities, such as foreign currency loans.

Based on the model, 1 percent rise in EURHUF exchange rate, meaning weakening of the forint against the euro, as expected, increases the sold foreign currency portfolio by 2.035 percent in the examined period, since a favourable hedging exchange rate becomes available.

Short currency positions are reduced by 17.6% on average in *December*. In case of a 1 percent increase in the *foreign currency market volatility*, the portfolio increases by 0.104 percent; it is also in line with the expectations based on the results of the theoretical model. From the above volatility data, the 30-day volatility of the forint against the euro proved to be determining; because of the correlation of the volatility data, additional volatility time series do not provide further explanatory power.

It is interesting that the change in EURIBOR was also included among the explanatory variables with a positive sign. This effect, contrary to the previous three explanatory variables, is difficult to be interpreted; a connection is likely via some latent variable.

The expected value of the forward sale is increased by the EURHUF swap difference, it is surprising that this factor was not included in the explanatory variables of the model and so the higher forward price arising from the difference in interests alone does not cause changes in the forward portfolio. The reason for this is possibly the strong relationship between the swap difference and the EURHUF spot rate.

The correlation between the explanatory variables is not significant, which is indicated by the tolerance value being close to 1, as well as its inverse, the variance inflation factor (VIF), the value of which is also close to one.

The partial correlations cleaned from effects of other explanatory variables are moderately strong in the case of the first three variables; it is the least strong in case of EURIBOR, which variable is difficult to be interpreted.

The distribution of the residuals slightly deviates from normal, which is confirmed by the result of the Kolmogorov-Smirnov test, p-value is 0.032.

All in all, the model is suitable for examining the relationship between the short forward position and the major market factors but about 40% of the variance is influenced by other factors like foreign trade and unsystematic effects.

6.2.3 Modelling long forward stock positions

Similarly to the explanation of changes in short forward position, the changes of long forward FX-position is also analysed in a linear regression model[63]. The explanatory variables are the market-, foreign trade- and calendar factors as described above, while the dependent variable is the change in the stock of long forward stock.

[63] The SPSS tables of the analysis are included in Appendix VII.

Three outlying months, critically different from the prediction of the model, can be identified, so I omitted them in order to improve the fitting; thus, the calculation was based on 96 months data. This model is significant at all conventional significance levels; the *p-value* of the *F statistics* is 0.001. Based on the *adjusted* R^2 indicator, the model explains about 46% of the total variance.

Table 16 summarizes the explanatory variables, the regression coefficients and associated other statistics of the model.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	.028	.010		2.712	.008					
December	-.248	.035	-.538	-7.083	.000	-.566	-.594	-.535	.988	1.012
EURHUF	-1.711	.368	-.366	-4.653	.000	-.282	-.436	-.351	.920	1.086
EURHUF_v_90	.236	.066	.284	3.581	.001	.239	.350	.270	.910	1.099

Table 16: Linear regression model of long forward position

Source: NBH, Bloomberg data analysed in SPSS

In explaining the long forward positions, the constant proved to be significant; so if all other factors remain unchanged, the monthly portfolio increases by 2.8%.

In case of the changes in long forward position, the *December effect* is the most significant, this variable was involved first. The year-end position maturities and closings reduce the overall portfolio by almost 25% on average. The other two explanatory variables, similarly to the model in the previous subsection, are the change in the *EURHUF exchange rate* and the *90-day volatility of EURHUF*. Weakening of the forint against the euro by 1 percent reduces the portfolio by 1.711%, in line with the expectations.

The growth of volatility – in conformity with the theoretical model – is in positive correlation with the portfolio increase; however, in the case of long positions, the 90 day volatility had the highest explanatory power, so it was included in the model as an explanatory variable. All the three explanatory variables are significant at a level higher than 99%, tolerance is close to 1, and the VIF value supports that the explanatory variables are uncorrelated.

The distribution of residuals can be considered normal; the *p-value* of the Kolmogorov-Smirnov test is 0.2.

The foreign trade turnover and the EURHUF swap difference were not included as explanatory variables, the reasons can be similar to those referred to in the case of the short positions: the foreign trade turnover and the timing of the hedging decision are different, or may vary, while the swap difference does not have an additional significant effect on the development of the portfolio due to its co-movement with the EURHUF exchange rate.

The effect of the explanatory variables developed in line with the expectations, but the model does not explain half of the total variance, which indicates the presence of further explanatory factors as well as the importance of individual factors also in case of long positions.

6.2.4 Results of the analysis of aggregate FX-volume and stocks

In this subsection, I analysed the aggregated turnover and stock data of foreign exchange transactions of non-banking resident partners as collected by the National Bank of Hungary. Turnover data were available both on option and forward transaction types; stock data were available on forward positions.

Based on the aggregate data, the following observations can be made regarding the hypotheses of method and execution of hedging.

Hypothesis 3, stating that "*The hedging ratio of currency risk depends on the direction of the exposure, it is higher for long foreign currency positions (against HUF).*" is confirmed by the analysis of forward stock data, since the volume of short forward position exceeds the volume of long position throughout the examined period.

The statement of hypothesis 4 "*The ratio of options in the hedging of foreign-exchange risk is negligible, but increasing.*" is supported by the turnover data; the proportion of options within derivative transactions is under 10%. Both the volume and the proportion of options increased during this period; however, this increase is determined by the growth of written transactions, so they served speculative purposes.

Hypothesis 7 “*The increasing volatility of the foreign exchange market increases hedging activity.*” is confirmed by the linear regression model explaining the changes in foreign currency portfolios, since the increase in implied volatility of the EURHUF exchange rate had a significant positive effect on the change of both long and short forward positions.

Hypotheses 8 stating “*Hedging activity increases with the rise of the expected value of the forward hedge position*”, is also supported by the regression model. The effect of the changes of EURHUF exchange rate depends on the direction of the position; the weakening of the forint (exchange rate increase) significantly reduced the long foreign currency position in the studied period, while increased the short position. The favourable change in the spot FX-market increased the derivative portfolio, as better hedging rate is available. However, the difference of the forward and spot exchange rates (swap-difference), which is the net expected value of hedging, did not significantly affect the portfolio. The explanation can be its strong connection with the spot rate.

Another interesting finding of this chapter is that the derivative portfolios at the end of the year; long positions by 25%, short positions by about 18% on a monthly basis.

6.3 Analysis of FX transactions in a commercial bank

While we can obtain an overall picture from the data of the National Bank of Hungary, further details of the corporate risk management of Hungarian companies can be obtained from enterprise-wide data. Customer data of commercial banks offering hedging solutions can help in the analysis. In order to investigate the enterprise-level risk management, a commercial bank operating in Hungary[64] provided me with data of all its spot and forward foreign exchange contracts between January 2008 and November 2012, indicating the client code, the sector, the date of conclusion, the value date, currency-pair and the amount.

[64] I do not provide the name of the bank in the analysis (as per its request); I refer to it as ‘commercial bank’.

The bank had a total of 481 clients dealing FX-transactions in the surveyed period, 336 of that were corporate clients. During the period, a total of 88,500 transactions were concluded, of which 38,708 with corporate clients. These data are included in Table 17.

All clients	481
Corporate clients	336
All transactions	88,500
Transactions with corporate clients	38,708

Table 17: FX-transactions between 2008 and 2012

Source: Commercial Bank

In the following, I analyse only the corporate sector transactions; the other partners are institutional clients, their transactions are not subject of the present research. I separated spot –up to 6-day difference between the value date and the date of conclusion– and forward transactions. By examining the development of the number of transactions in each year (Table 18), it can be observed that forward transactions make up about half of all transactions.

	All transactions	**Forward transactions**	**Forward/All**
2008	4,792	2,080	43%
2009	8,221	3,939	48%
2010	8,366	3,922	47%
2011	9,354	4,521	48%
2012*	7,975	3,841	48%
All	**38,708**	**18,303**	**47%**

*until November

Table 18: FX-transactions by deal type between 2008 and 2012

Source: Commercial Bank

We can see from the number of companies dealing the FX-transactions, that while 336 corporate clients transact with the bank, only 30% of them, 102 clients conclude forward transactions as well.

Considering that the bank's customers are large companies, it is apparent that even within this set of companies, only a minor part manages its risk actively. Table 19 shows the frequency distribution of companies dealing on forward according to the *number of transactions* broken down by years.

Item	2008	2009	2010	2011	2012
0-4	23	17	13	17	11
5-9	8	8	6	7	10
10-19	10	9	6	13	12
20-49	10	11	11	6	4
50-99	3	4	5	2	2
100-199	5	3	4	7	3
200-499	0	2	4	4	4
500-	1	2	2	2	3
All	**60**	**56**	**51**	**58**	**49**

Table 19: Corporate clients having FX-transactions according to deal-number between 2008 and 2012

Source: Commercial Bank

50 to 60 corporate customers concluded forward transactions per year between 2008 and 2012, and about 15% of the customers changed in each year on average.

The distribution of transactions developed similarly during the period, the majority of customers has only a few –less than 10– transactions per year, but there are clients with hundreds of transactions as well. The interpretation of the number of transactions is more difficult, as a significant number of clients close their forward positions before maturity by an opposite forward transaction; consequently more transactions can be associated with the hedging of a particular exposure.

The *average maturity* of forward transactions is 112 days, or about three and a half months. The frequency of transactions based on their maturity is shown in Figure 24. The proportion of transactions with a maturity of up to a month is the largest, above 28%, 62% of all transactions have a maturity of up to 3 months, and maturities longer than 1 year constitutes only 6%, while the maximum maturity is three years. This supports hypothesis 6 which states that foreign exchange risk management with derivative instruments is performed for short term.

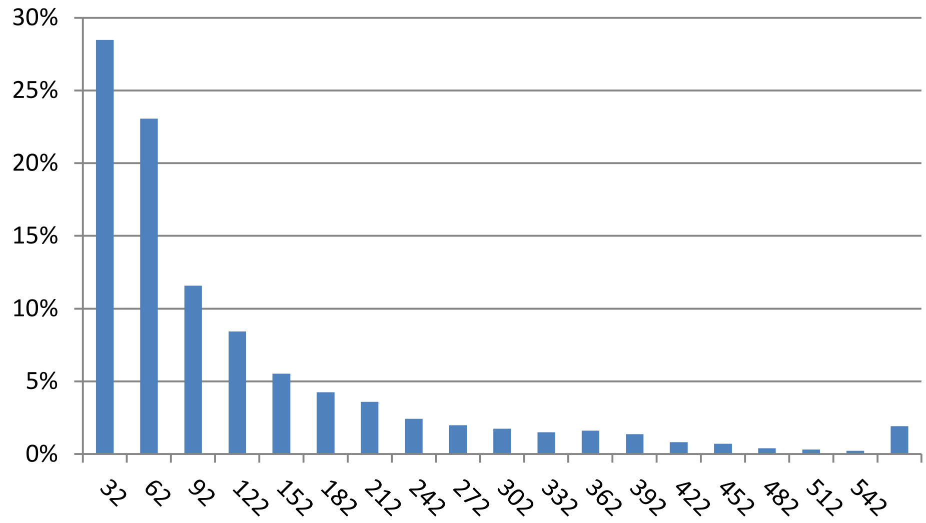


Figure 24: Forward transactions according to tenor (in days) between 2008 and 2012

Source: Commercial Bank

Table 20 shows the *distribution* of forward transactions *by currencies.*

	Item	% of all transactions*
AUD	1	0,01%
CAD	38	0,21%
CHF	158	0,86%
CZK	25	0,14%
EUR	11,930	65,18%
GBP	86	0,47%
HUF	16,821	91,90%
JPY	39	0,21%
PLN	16	0,09%
RON	195	1,07%
RUB	127	0,69%
SKK	2	0,01%
USD	7,168	39,16%

* All is 200%, as a transaction includes 2 currencies

Table 20: Forward transactions according to currency between 2008 and 2012

Source: Commercial Bank

It can be seen that transactions against the forint constitute more than 91% of all transactions, 65% of forward transactions is in euros and 39% is in dollars. Other currencies obtain a share of maximum 1.07% (Romanian lei); others are less than 1%.

In the following, I examine the transactions including euro, dollar or forint; as these account for 96% of all transactions.

Sold currency (by client)	Bought currency (by client)			
	EUR	**HUF**	**USD**	**All**
EUR		5,567	656	6,223
HUF	4,934		4,080	9,014
USD	719	1,660		2,379
All	**5,653**	**7,227**	**4,736**	**17,616**

Table 21: Forward transactions according to currency-pair between 2008 and 2012

Source: Commercial Bank

According to Table 21, although in relation to EURHUF clients sell the euro on forward in the majority of the transactions, in case of USDHUF, forward dollar purchases dominate. Since the above figures do not show the value of the transaction, Table 22 is worth examining, as it includes the characteristics of forward transactions per currency pairs and directions.

		EURHUF sales	**EURHUF purchase**	**USDHUF sales**	**USDHUF purchase**	**EURUSD sales**	**EURUSD purchase**
Amount (million base currency)	average	0.696	0.849	1.578	0.525	0.911	1.554
	total	3,875	4,188	2,620	2,142	598	1,117
	min.	0.0001	0.0011	0.0009	0.0045	0.0073	0.002
	max.	70.079	54.100	55.579	35.000	22.166	20.000
Tenor (in days)	average	168	91	95	85	78	116
	st. deviation	207	97	88	87	78	118
	min.	7	7	7	7	7	7
	max.	1,098	622	661	551	393	587

Table 22: Volume and tenor of FX-forward contracts by currency-pair between 2008 and 2012

Source: Commercial Bank

Based on the aggregate volume, while corporate clients sell euro against forint in more transactions then they buy it in; however, the average size of these transactions is below the volume of forward euro purchases, so the total volume of euro long forward position exceeds the short euro position. In the case of dollar/forint forward position, it is on the contrary; dollar is bought in more transactions, but the average transaction volume of dollar sales is three times that of the dollar purchases, so as a total volume, dollar sales exceeds the dollar buying.

As the basic exposure of the clients is unknown, no conclusions can be drawn about the hedging patterns from the above findings. The other half of Table 22 can be better interpreted because here we can compare the *maturity* of different transactions. During the studied period, forint interest rates were higher than the interest of euro investments, so forward exchange rate were higher than spot rate, and this difference increased with the maturity. Consequently the theoretical model suggests hedging for a shorter maturity in case of short foreign currency exposure, on the other hand, the positive expected value of a forward sales is to be used through as long maturity as possible. Figure 25 shows the distributions of long and short euro forward transactions according to the tenor of the deal.

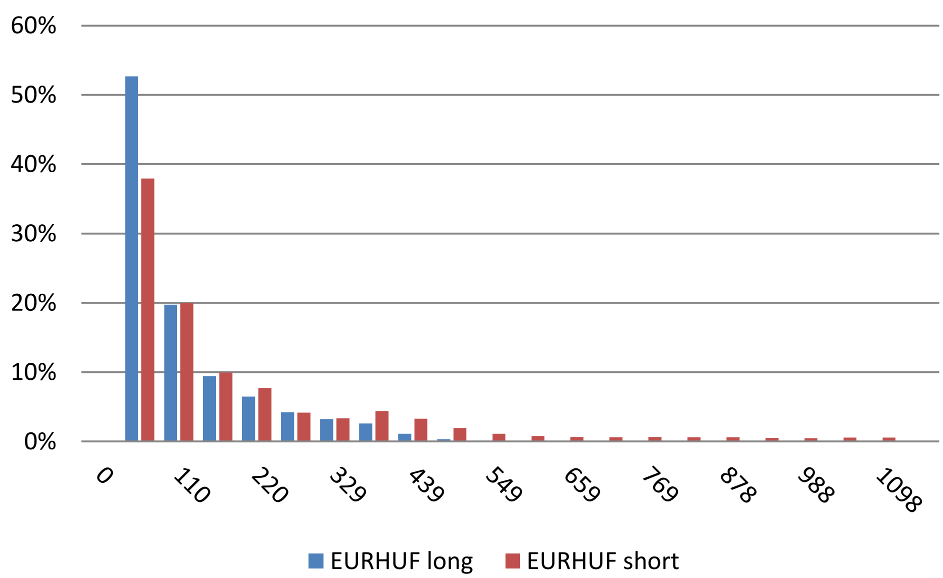


Figure 25: Tenor (days) of EURHUF transactions between 2008 and 2012

Source: Commercial Bank

The analysis of the EURHUF transactions confirms the model, as the average maturity of euro short forward deals (168 days) highly exceeds the average maturity of long forward transactions (91 days). The longest euro long forward position had a maturity of 622 days (1.7 years), while the tenor of some forward euro sales is longer than three years. In case of long euro positions 2.15% of all transactions had a maturity exceeding 1 year, while nearly 14% of short forward euro transactions had a maturity of over one year.

The conclusions of the analysis of the bank transactions are as follows. Only a small group of Hungarian companies apply proactive risk management; only 30% of the clients of the bank, which are large companies having foreign currency exposure, conclude forward contracts in addition to spot foreign currency exchange transactions.

The analysis of transactions based on their maturity confirms Hypothesis 6, which proposes that "*The foreign-exchange risk is hedged by derivatives in the short term.*" Both the average and the distribution of the maturity support the assumption of the theoretical model that companies take into account also the *expected value of the hedging transaction*, when making hedging decisions.

6.4 Results of the corporate risk management survey

By evaluating the information based on the bank's data, we have to consider the fact that a company typically partners and concludes hedging transactions with several banks. In order to obtain a better understanding of their hedging practices, I carried out a company survey as well, using a questionnaire sent out to the clientele of the above mentioned commercial bank. Linking the survey data with the bank database is not possible because of the promised anonymity. The surveyed clientele consists exclusively of large companies; the customer base of the bank is basically comprised of TOP 500 companies. All of the bank's active clients (at the time of the data collection in the first half of 2013) were approached, so the sampling method is a form of *cluster sampling*.

The *data collection* was implemented through a password-protected questionnaire of an online interface. The questionnaire is included in Annex VIII. I received 15 responses through the online interface and 10 questionnaires were sent back in e-mail; together with personal interviews, I obtained a total of 29 responses. This, taking into account the data of the previous chapter, means a response rate of about 30%.

When designing the questionnaire, I relied on the experiences of the bank; our goal was to investigate corporate risk management practices as extensively as possible, with special regard to liquidity considerations. The questions concerned, firstly, the financial details of the companies, secondly, the implementation of risk management, and thirdly, the subjective value judgment of the respondents about the company's risk management.

6.4.1 Descriptive analysis of the survey data

Although the respondents belong to the small corporate clientele which engages in active risk management activities, only slightly more than half of respondents (55%) have a *risk management* strategy established in writing. This is consistent with the findings of the literature presented earlier in this chapter, which states that the conscious management of foreign exchange risk is not typical in Hungary. 55% of the *companies with a risk management strategy* stated that the purpose of risk management is to reduce the volatility of the corporate earnings; and in 45% of the cases, the maximization of earnings also appeared as a risk management objective.

This supports the assumption of the theoretical part of this thesis, that the expected value of the hedging transaction also plays a role in hedging decisions. 85% of respondents replied that they either do not pay attention to the risk management strategy of *competitors*, or although they are aware of it, it does not influence the risk management decisions of the company. Only 15% of them stated in their response that the risk management strategy of competitors is taken into account during decision-making.

The companies surveyed have at least two banking relationships, more than half of them have above 5 *banking partners*. This is not surprising, since the clientele selected is the key target group of banks providing treasury services, and they presumably received offers from all banks operating in Hungary.

Although almost every company has a position exposed to interest rate risk, as I assumed in the second hypothesis, they typically do not hedge the risk of changes in interest rates; only 20% of them use derivative transactions to manage these risks. 40% of respondents argued that due to the size of the position, the risk is negligible, while 24% did not consider the hedging of the interest rate risk cost-effective for the company that demonstrates the role of the expected value of the hedging position in risk management decisions.

86% of the companies conclude derivative transactions to hedge their *foreign currency* risk; out of these companies, all use forward agreements, 21% of them trade options, and 24% structured products. So the most frequently used instrument is the forward agreement but 20 to 25% of the companies engaged in active risk management utilise option hedging as well.

Two-third of the hedgers report to *underhedge* their exposure (hedging ratio is below 100%), which is primarily justified by the lack of precise knowledge about the exposure, and only secondarily the fear of possible financial loss. Nearly one-third of companies hedge their exposure perfectly (hedging ratio is 100%) and a single company responded to overhedge its position.

The data of hedging ratio according to the derivative type show - consistently with hypothesis 5 - that in case of companies using option hedging as well, the *hedging ratio* is significantly higher. Table 23 contains the average hedging ratio both for companies using option hedging and the ones that do not. Due to their initial fee, option transactions appear to be less attractive hedging solutions; however, as we have seen in Chapter 5, if the company is able to finance the position, even over-hedging can be optimal.

	Option-no	*Option-yes*
Expected value	0.60	1.00
Variance	0.14	0.02
Observations	23.00	5.00

Table 23: Corporate hedging ratio depending on the usage of options

Source: own calculation based on the survey data

About half of the respondents have an internationally accepted derivative frame contract: an ISDA *master agreement*, while 65% and 31% of them have a forward and an option frame contract respectively. 10% of respondents reported to have exclusively FX conversion contract that allows for the conclusion of spot transactions only.

87.5% of the companies using derivatives account for their transactions in accordance with the Hungarian *accounting rules*; a quarter of these companies simultaneously keeping accounts according to the IFRS as well. 12.5% keeps accounts in conformity with the accounting requirements of the IFRS exclusively. *Hedge accounting*, which allows for the joint accounting treatment of the hedge transaction and the underlying exposure, is used by a quarter of respondents.

As I have already pointed out, hedging with derivative instruments makes it possible to manage the company's market risks only i*n the short term*; the structural changes of the risk factor, the exchange rate, need to be managed by the company strategy. Exchange rate hedging transactions - as it is revealed by the data in the previous subsection - generally expire within one and a half years; however, 72% of respondents deal for less than half a year on average. Interestingly, although in recent years, forward foreign currency sales had a positive expected value, and thus typically exporting companies hedged for longer terms, as also confirmed by the analysis of foreign currency transactions, based on the survey responses, there is no statistically significant difference in the hedging maturity depending on the direction of exposure.

The questionnaire asked about the *collateral requirements* necessary for dealing derivative transactions. 86% of respondents have no initial margin obligation, and only 25% is required to collateralize their exposure either initially or above a specified level of unrealised losses. The responses and related interviews clearly showed that the banking risk appetite against the largest corporations are still high, they can get easily financing both in form of creditline and margin line. Consequently, largest corporations do not face financing constraints when hedging; therefore, financing costs have no significant effect on their hedging strategies.

6.4.2 Risk management and corporate size

Although the clients of the bank, especially those with active treasury relationship, are large corporations, I examined the *company size* and the *level of the risk management* based on the sample, and also the relationship between them.

Company size can be interpreted in multiple dimensions; the survey contained several pieces of data from the annual report characteristic of the firm-size, out of which I used the ones included in Table 24 and carried out *principal component analysis*.

Financial statement data	**Short name**
Total assets	MF2011
Equity	ST2011
Net sales	Arbev2011
Number of empoloyees	Letszam
Operating profit	Op_profit2011
Pre-tax profit	Ptax_profit2011

Table 24: Variable used to determine corporate size

Source: own analysis

Using the principal component analysis method, we can identify uncorrelated latent variables under the correlated variables; in this case, we are looking for *factors representing the size of the company*.

The correlation is high between the studied variables: 0.687 - 0.999, the KMO measure is 0.717, and thus the data is suitable for principal component analysis. Because of the strong relationship between the variables, one major component explains 89.5% of the total variance, so the data can be condensed into a single "size" factor. By plotting the companies in two dimensions using multidimensional scaling (Fig. 26), it is apparent that, based on the above data, the companies are fundamentally dispersed along a single dimension, only one company shows a different characteristic in the other dimension. The two-dimensional graph is excellent, the stress value is 0.003, the R^2 index measuring the conformity of the data and the distance is 0.9999.

Consequently, size can be quantified with a single variable, thus by saving the factor score of each company based on the principal component analysis, we obtain a *variable representing company size*, which I am going to compare with the variable representing the risk management quality.

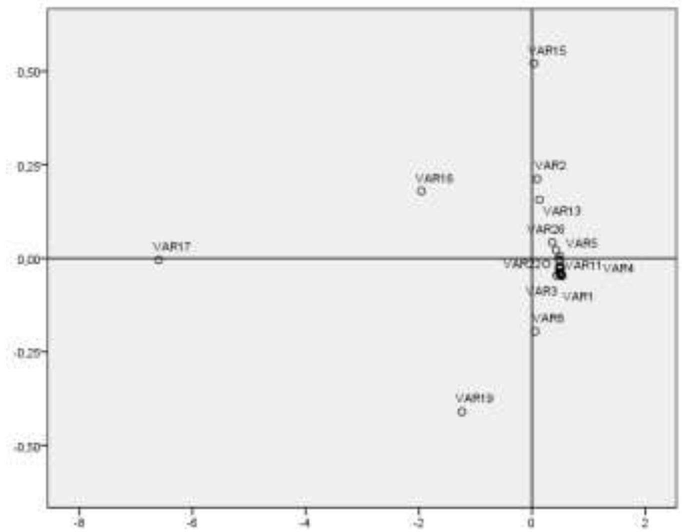


Figure 26: Scaling of corporations in two dimensions according to the size

Source: own calculation based on the survey data

In order to quantify the risk management quality of the company, I used *objective* and *subjective* survey variables. The objective variables cover the answers to the risk management practice of the firm, such as whether the company has a written risk management strategy. These are binary variables. On the other hand, respondents evaluated the risk management of the firm according to several criteria, on a 1 to 9 scale. Table 25 shows the *objective* and *subjective variables* used to the analysis.

Objective variables	**Short name**
The firm has a (written) risk management strategy.	Strat
FX-risk is managed by matching the positions (natural hedge).	Term_fed
FX-risk is hedged with derivatives.	Deriv_alk
Interest rate risk is managed.	Kamat_fed
Hedge accounting is used to the accounting of derivatives.	Fed_konyv
The risk of the hedge position is measured.	Kock_meres
Subjective variables	
The risk management strategy is eligible.	Strategia
The implementation of risk management is consistent.	Vegrehajtas
Our banking partners help is managing risk.	Bankok
We are fully confident about the features of hedging transactions.	Felkeszultseg
Hedging transactions support corporate operation.	Fed_ugyletek

Table 25: Variables used to the analysis of corporate risk management quality

Source: own analysis

The objective criteria are *binary variables*, their value is one if the statement is true for the company and zero if it is not. The KMO measure of the principal component analysis of the objective criteria was below 0.5; therefore, that sample is not suitable for principal component analysis. According to the KMO measures of the individual variables, two variables, hedging of the interest rate risk and managing the FX-risk with natural hedging, proved to be unsuitable; therefore, I omitted this two, and performed the analysis with the other four. The omitted two variables are indeed not necessarily related to the quality of risk management, since most of the companies, as stated on the second hypothesis, do not typically hedge the interest rate risk. As for natural hedging, it can be part of a proactive risk management policy, but it is also possible that the company have not adequately assessed the potential risks and hedging options. The KMO measure of the four-variable analysis is 0.596, and the 0.016 value of the Bartlett test also indicates that the hypothesis of independence of the variables can be rejected.

Two components were identified which explain 73% of the total variance. Table 26 shows the correlations between the two principal components and the original variables.

	Components	
	1	2
Strat	0.823	0.286
Deriv_alk	0.292	0.741
Fed_konyv	0.894	-0.011
Kock_meres	-0.023	0.864

Table 26: Correlation between the components of risk management quality and the objective variables

Source: own analysis

One component is related to *risk management administration*, and strongly correlates with the written strategy and the application of hedge accounting variables. The other component correlates with the *application of derivative transactions* for hedging purposes, as well as with the *measurement of risk* of hedging transactions. The objective measure for the quality of risk management was determined as the sum of the factor scores of the two components. It is worth noting that this sum provides the same result as we could obtain based on the value of a single component by querying one factor.

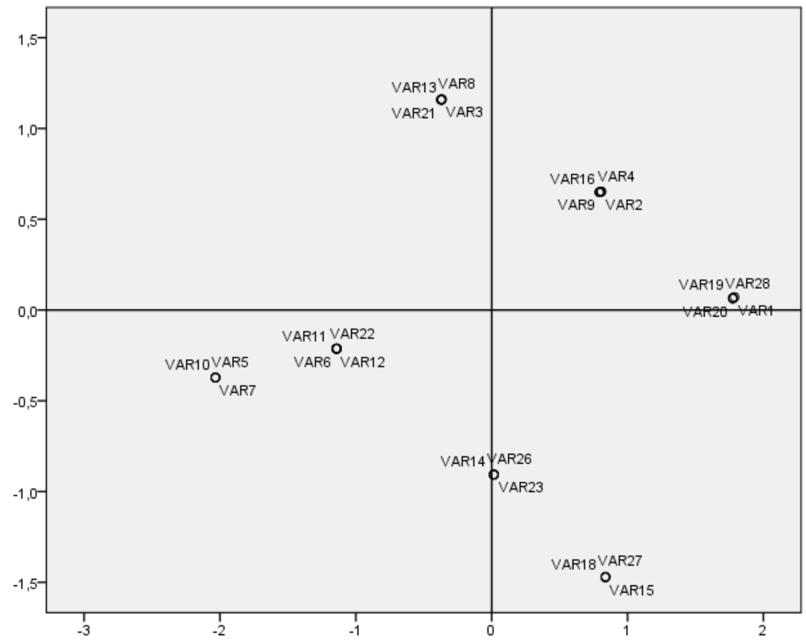


Figure 27: Respondent corporations according to the objective criteria of risk management

Source: analysis of the survey data in SPSS

In Figure 27 the companies are plotted in two dimensions using multidimensional scaling; the 0.09 stress value shows a good fit; the R^2 is 0.95.

The value of the subjective variables is 1 to 9, where 1 means that the respondent does not consider the statement true for the company at all, and in case of 9, the respondent thinks it entirely true. Based on the values of the responses, I performed principal component analysis again, the aim was again to identify the indicators for measuring the quality of risk management; however in this case, it was determined by the value judgment of the respondent. The resulting KMO measure is 0.704, and the hypothesis of the independence of the variables can also be rejected on the basis of the Bartlett test at all conventional significance levels. One component was selected, which retained 73% of the total variance. The correlation between the component and the variables is strong and positive, it varies between 0.77 and 0.93. The obtained factor scores show the subjective evaluation of risk management.

Since evaluation on the multi-point scale is greatly affected by the respondent's personality, it is worth examining the *centred variables* as well, which indicate which statements did the respondent evaluate as better or worse than their own average. To do this, I subtracted the average value of the given company from each value, and performed the analysis with the resulting values, centred for the company. According to the centred values, 2 main components can be identified; the first encompasses 64.5% of the total variance, while the second a further 22%. In Table 27, the rotated component matrix shows correlations of the components and the original variables.

	Components	
	1	2
Strategia_cent	0.942	-0.117
Vegrehajtas_cent	0.929	-0.172
Bankok_cent	-0.858	-0.233
Felkeszultseg_cent	-0.005	0.998
Fed_ugyletek_cent	-0.861	-0.066

Table 27: Correlation between the components of risk management quality and the centered subjective variables

Source: analysis of the survey data in SPSS

The first component shows strong positive correlation with statements, which evaluate the risk management strategy of the company and its implementation, and shows strong negative correlation with the opinion of the respondents concerning the services provided by the banks and the usefulness of hedging transactions. The better the opinion of the own risk management strategy, the less satisfied firms are (relatively) with the banking services, and also with the hedging transactions.

The risk management attitude of the company, how the respondent evaluates the knowledge of the company regarding hedging transactions, appears in a separate component. Figure 28 shows the variables in the space of the components. We can see that the opinion on how familiar the company is with the characteristics of hedging transactions does not correlate with other statements evaluating corporate risk management.

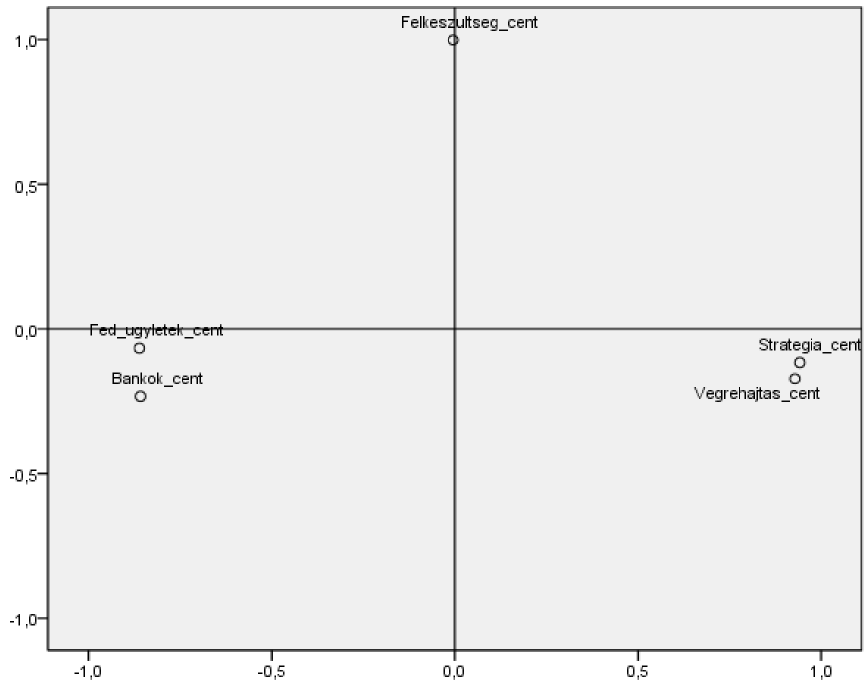


Figure 28: The centered subjective variables in two dimensions

Source: analysis of the survey data in SPSS

The aim of this subsection is to compare *company size and the quality of risk management*. To do this, I examine the *correlation of the factor scores* of the latent variables measuring the size and quality of risk management, identified as components.

Factor	Short name
Corporate size	meret
Risk management first objective factor	obj_fakt1
Risk management second objective factor	obj_fakt2
Sum of risk management objective factors	obj_fakt_össz
Risk management subjective factor	kk_szubj_fakt
Risk management first subjective factor based on centered variables	szubj_cent_1
Risk management second subjective factor based on centered variables	szubj_cent_2
Sum of risk management subjective factors based on centered variables	szubj_fakt_cent_össz

Table 28: Factors of corporate size and quality of risk management

Source: analysis of the survey data in SPSS

I identified a single factor for size but determined multiple factors for the quality of risk management; these are included in Table 28 together with their short names.

Figure 29 presents the above factors, as functions of each other.

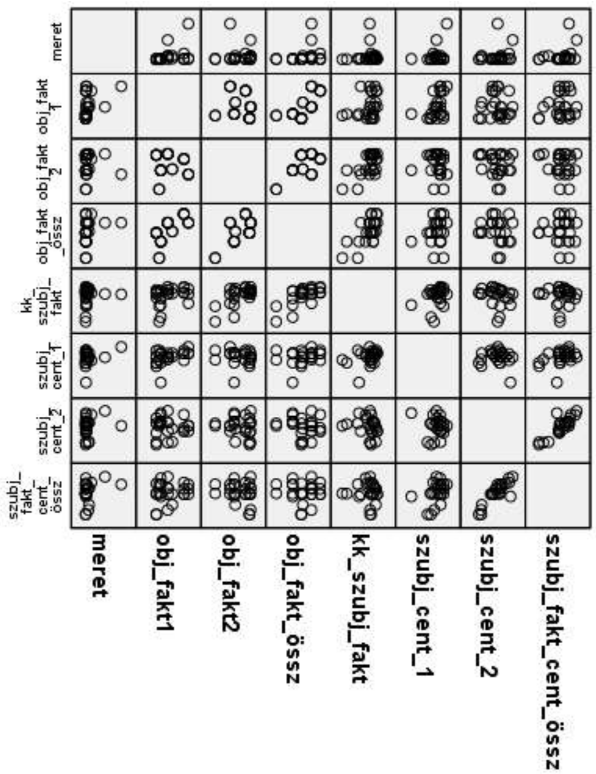


Figure 29: Relationship of corporate size and risk management quality

Source: analysis of the survey data in SPSS

According to the above figure, only those factors are strongly correlated, which are derived from each other, and thus trivially related, such as between the factors objective 1 and 2 and the factor "sum" calculated as their sum, and similarly, in the case of centred subjective factors.

Table 29 displays Pearson's *correlation coefficients* between the factors –in bold–, and their *significance* (*p-values*) –in regular type underneath. Red colour indicates values that are acceptable at a 99% significance level, and blue those that are acceptable at 95% significance level.

	meret	obj_ fakt1	obj_ fakt2	obj_fakt _össz	kk_szubj _fakt	szubj_ cent_1	szubj_ cent_2	szubj_ fakt_cent_ össz
meret	**1.00**	**0.35**	**-0.04**	**0.24**	**0.10**	**0.08**	**0.17**	**0.17**
		0.08	0.86	0.23	0.62	0.70	0.39	0.39
obj_fakt1	**0.35**	**1.00**	**0.00**	**.707**	**0.32**	**.415**	**-0.06**	**0.20**
	0.08		1.00	0.00	0.10	0.03	0.77	0.31
obj_fakt2	**-0.04**	**0.00**	**1.00**	**.707**	**.672**	**0.15**	**-0.24**	**-0.13**
	0.86	1.00		0.00	0.00	0.45	0.23	0.51
obj_fakt_össz	**0.24**	**.707**	**.707**	**1.00**	**.702**	**.399**	**-0.21**	**0.05**
	0.23	0.00	0.00		0.00	0.04	0.30	0.81
kk_szubj_fakt	**0.10**	**0.32**	**.672**	**.702**	**1.00**	**0.07**	**-0.28**	**-0.15**
	0.62	0.10	0.00	0.00		0.74	0.14	0.44
szubj_cent_1	**0.08**	**.415**	**0.15**	**.399**	**0.07**	**1.00**	**0.00**	**.707**
	0.70	0.03	0.45	0.04	0.74		1.00	0.00
szubj_cent_2	**0.17**	**-0.06**	**-0.24**	**-0.21**	**-0.28**	**0.00**	**1.00**	**.707**
	0.39	0.77	0.23	0.30	0.14	1.00		0.00
szubj_fakt_cent_össz	**0.17**	**0.20**	**-0.13**	**0.05**	**-0.15**	**.707**	**.707**	**1.00**
	0.39	0.31	0.51	0.81	0.44	0.00	0.00	

Table 29: Correlation of corporate size and risk management quality

Source: analysis of the survey data in SPSS

The size factor, contrary to the assumptions of the first hypothesis, does not correlate with any indicators of risk management quality. It can probably be explained by the fact that the study included only large corporations that are actively engaged in risk management, and they cannot be further differentiated according to the size.

It is interesting to look at the correlations of risk factors with each other. Although we are searching for the same underlying variable, the results vary depending on the type of responses analysed, and the method used. Besides the trivially related variables already mentioned, significant correlation at 99% level exists between the *risk management subjective factor* (obtained without centring) and the *second factor according to objective variables*, which is determined by the use of derivative transactions and the measurement of the risk of the hedge position.

In addition, the correlation between the first subjective factor, that is corporate strategy and implementation, obtained by centring, and the first objective factor, that is corporate strategy and hedge accounting, is significant at the 95% level.

6.4.3 Summary of the survey results

Based on the questionnaire survey, the hypotheses formulated are evaluated as follows.

The data did not confirm the *first hypothesis* proposing a correlation between company *size and the quality of risk management*; there is no significant correlation between the size and any of the risk management factors identified with the help of principal component analysis. However, the group of corporations surveyed are likely to be significantly distinct from small and medium-sized companies which are not engaged in risk management at all; and the results show that among large corporations, size is not an additional differentiating factor.

The second hypothesis was confirmed by the analysis; positions exposed to interest rate risk are typically not hedged by the companies.

The third hypothesis is not supported by the responses given to the questionnaire; based on the *direction of the exposure*, there is no significant difference in either the hedging ratio, or the hedge horizon. However, the *hedging ratio,* in accordance with the fifth hypothesis, is significantly higher in case of those companies that trade option transactions as well.

Derivative transactions with hedging purposes are typically concluded with a horizon of one and a half years or less; however, most transactions are even shorter maturing in half a year or less. This confirms the assumption of the sixth hypothesis, according to which derivative instruments can be used to hedge short-term risks.

The eighth hypothesis is supported by the results of the survey indirectly, since nearly half of the companies indicated the *maximization of company profit* as an objective of risk management.

The effect of the funding liquidity, which plays a central role in the thesis, is not significant in case of the surveyed companies. The majority of them (86%) have no initial margin obligation, and only a quarter of them are required to collateralize the unrealized loss of their positions. In the future, this is likely to change since the aim of the Basel regulations, providing a framework for the risk management of banks, is to reduce the vulnerability of the financial system as a whole; therefore one focus of the latest guidelines is the reduction of partner risks. Another objective of the regulators is the central clearing of standardized

OTC products, similarly to the exchange traded transactions. These changes will probably give rise to margin requirements of over-the-counter products as well.

7 CONCLUSION

In consequence of the crisis the regulations and the risk management of the financial institutions focuses on the monitoring and controlling the partner risk and the daily settlement of the derivative positions is under introduction even on OTC markets, so the topic of the thesis, the funding liquidity has become even more actual, since I started to work on it.

While theoretically OTC derivatives (forwards) are free of liquidity risk, as they do not generate any cash-flow until maturity, according to the practice banks are willing to take the credit risk of the non-realised loss of the derivative transactions only until a certain level, beyond that they request collateral from their partners. This practice appears in the documentation in the form of CSA (Credit Support Annex) of the ISDA contracts, containing the conditions of the mutual collateralization. The European Market Infrastructure Regulation (EMIR) accepted by the European Union, enacts the central clearing of standardized OTC derivatives above a certain notional amount. Therefore the OTC derivatives become path dependent products; their value is subject to the price movement of the underlying asset during the lifetime.

Consequently risk management has to consider the financing need of the hedging derivatives, so it affects the optimal financial decision that can explain the wide range of offered derivative instruments and the common practise of over- and underhedging.

The first three chapters of the thesis include the literature review.

The first chapter presents some case studies, which motivated the research. The financial downturns presented illustrate that although the future convergence of the prices of the exposure and the hedging derivative ensures value compliance and a minimal variance at the expiry, but during the lifetime of the deal, permanent and significant differences may arise, causing considerable fluctuations in the cash-flow. Even for a huge market player like Long Term Capital Management was in 1998, it is not always possible to obtain financing. Due to the lack of unlimited liquidity, the market players have to be prepared for the financing of high leverage positions like derivatives.

The second chapter gives an overview of the concepts of risk and risk management, and it analyses the relevance of individual and corporate risk management. The value of risk management can be derived from the individual utility function, while the corporate risk management is to be explained by market imperfectness and management incentives. Although utility function is interpreted for individuals, the corporate utility function is used to incorporate the explicit and implicit costs of financial distresses.

The theories incorporating the financial need of hedging are introduced in the third chapter. The optimal hedging ratio is modelled by the trade-off of the increased utility of the volatility reduction and the costs of financing or with the risk of the position liquidation.

The second part of the thesis contains the results of the own research.

In the fourth chapter I examine the optimal hedging in an own model, based on the results of the literature. This model lifts the assumption used in the literature of zero expected value from the hedging position, so hedging affects not only the variance of profit, and through financing costs its extent, but the expected value of the hedge also has an impact. An exporting company tends to hedge less, if it expects a favourable market movement. So the model keeps the path-dependency of the former models, but it extends the analysis with the expected value of the hedge position. The hedging affects not only the variance of the profit and through the financing costs its extent, but the expected value of the hedge has an impact also. The lower and upper bounds of the optimal hedge ratio are derived, the analysis presents that the expected value of the hedging position can justify not only the underhedge but oven the overhedging of the exposure. The financing cost decreases the extent of over- and underhedge in all cases, it lowers the upper bound, while enhances the lower bound of the optimal hedging. The exact value of the hedging ratio is a function of market- and corporate specific parameters, and it is quantified in several simulations. Furthermore, I analyses the effect of non-static financing costs, where the credit spread is a function of the financing need as well.

The other direction of the analysis is the investigation of the optimal hedge ratio in a multistage framework. In the model of the fifth chapter the hedge position needs to be financed several time during its lifetime, on the other hand the hedging position itself is concluded for more maturities. The optimal hedging ratio based on the expected utility of different hedging strategies is analysed. The funding risk appears in the model not only as the potential cost of the credit spread, but explicit financial constraints of the financing are built in also. Therefore the risk management solution is not always, but at a certain (high) probability optimal. The risk factor is the fluctuation of the euro exchange rate against the Hungarian forint, which is simulated in a GARCH(1,1) model. Different hedging strategies are compared based on their expected utility, and the optimal hedging ratio of those strategies is analysed through Monte Carlo simulations. The simulations illustrate, that in the presence of liquidity risk option hedge is optimal, as the financing need is foreseen.

The sixth chapter presents the empirical research, aiming to assess the risk management practice of the Hungarian firms and to confirm the validity of the theoretical model. Based on the practice and the theoretical model 8 hypotheses were formulated, covering the risk awareness of the firms, the hedging method and the execution of hedging. Data from three sources are used to confirm the statements: statistics of foreign exchange market transactions and derivative stocks collected by the National Bank of Hungary (NBH), the time series of the foreign exchange transactions of a Hungarian commercial bank and the results of a survey.

The results the empirical analysis are the following.

Hypothesis 1 stated: “*Risk awareness and the size of the firm are correlated.”* That is to be analysed based only on the survey data, as the aggregate NBH and bank data do not contain firm-specific information. Neither does the theoretical model include the size of the firm, so this is the only hypothesis not answered by the model.

The survey contained several pieces of data from the annual report characteristic of the firm-size that correlate with each other. The latent factors of the size were searched by principal component analysis. I found one significant component which explains more than 89% of the total variance. Consequently, size can be quantified by a single variable that is given by factor scores.

In order to quantify the risk management quality of the company, I used objective and subjective survey variables. The objective variables cover the answers to the risk management practice of the firm, such as whether the company has a written risk management strategy. These are binary variables. On the other hand, respondents evaluated the risk management of the firm according to several criteria, on a 1 to 9 scale. Based on the objective variables, two components were identified, the first connected to the administration of the risk management, the second to the usage of derivatives.

The subjective factors were analysed in two different ways. First I used the original values, and then I centralized them by subtracting the average of the respondent. The first method resulted in a single, the second method two uncorrelated variables, whose factor scores were also saved. By examining the correlation between size and the five different risk-awareness factors, I found no correlation. The reason for that is probably the fact that the firms in the sample belong to large corporations where size is not a further differentiating factor.

Hypothesis 2 „ *Hungarian corporations do not hedge their positions exposed to interest rate risk.*" The management of interest rate risk differs from that of the foreign-exchange risk, as it cannot be eliminated completely. Changing a variable interest rate to a fixed one means replacing value risk with cash-flow risk. Interest rate risk in the above statement refers to fixing the floating rate paid for the credit. Based on the model, the increasing yield curve results in higher costs in the short term, and because of the enhanced financing need, hedging with interest derivatives is suboptimal. The survey data confirmed that only 20% of the respondents hedge their open interest rate position.

The following hypotheses refer to the hedge of foreign-exchange risk.

Hypothesis 3 „ *The hedging ratio of currency risk depends on the direction of the exposure; it is higher for long foreign currency positions (against HUF).*" is derived from the high swap-difference of the period examined that leads to an increasing forward price. Consequently, the forward sale of the foreign currency (euro) has a positive expected value, while buying the foreign currency on forward has a negative expected value. The expected value of the hedge causes the overhedge of the long euro and underhedge of the short euro positions.

Similarly, the aggregate short forward position was double that of the long forward position in the period examined.

In contrast with the above, there is no significant difference in the hedging ratio of the exporting and importing companies, according to the answers given for the survey.

Hypothesis 4 „ *The ratio of options in the hedging of foreign-exchange risk is negligible, but increasing.*" The first part of that statement is justified by the model through the initial financing costs of the options. The analysis of the derivative transactions had the same result; the ratio of options is less than 10% of all derivative trades. Although the volume of option trades increased before the crisis, that was due to the growing volume of sold option aiming to profit from the huge swap-difference and stable price movement of the period. These speculative positions suffered essential losses as a consequence of increased volatility and extreme price changes in the crisis that resulted in a sudden fall of the option trades. Since then, the ratio of bought options moves between 3-5% of the derivative transactions while the short option positions amount to 5-10% of the total volume.

Hypothesis 5 *„ The hedging ratio depends on the applied derivative (forward, option)"* is illustrated in the analysis of the former subchapter. The results of the simulation of different fx-risk hedging strategies give a wide range of over- and underhedge in the optimum.

Based on the answers of the survey, the hedge ratio is much higher if the firm also uses options for hedge.

Financial hedging can offer a short term solution, as stated in **Hypothesis 6** *„ The foreign-exchange risk is hedged by derivatives in the short term."* Although volatility increases over time, as does the utility of the hedge, volatility also causes increased variability of financing costs, which lowers the utility. Thus, beyond a certain future time period the liquidity risk of the hedge exceeds its utility, making hedging not at all optimal.

The survey data and bank transactions confirmed this statement as well; most of the hedging positions expire in 6 months, and forwards longer than 1.5 years are very rare.

Two statements on the execution of hedging are analysed together. According to **Hypothesis 7** "*The increasing volatility of the foreign exchange market increases hedging activity."* and **Hypothesis 8** states "*Hedging activity increases with the rise of the expected value of the forward hedge position."*

Both factors – the volatility of the underlying asset and the expected value of the hedge position – increase the hedge ratio in the model.

The significant explanatory variable in the linear regression model turned out to be the change in the EURHUF spot exchange rate and the change in volatility. As assumed, the beta of the volatility is positive in the case of both – long and short – forward positions.

Increasing volatility causes a rise in the stocks independent of the direction of the exposure. The effect of the exchange rate is – as expected – positive for short foreign currency positions and negative for long foreign currency positions.

The difference between the forward and spot prices determining the expected value of the hedge in fact proved to be insignificant because of its high correlation with the spot exchange rate.

According to the survey answers, almost 50% of the hedging firms consider the maximization of profit to be the aim of risk management.

The results are summarized in the following table.

Risk awareness, managed risk types	**MNB data**	**Bank data**	**Survey**
H1: Risk awareness and the size of the firm are correlated.			-
H2: Hungarian corporations do not hedge their positions exposed to interest rate risk.			+
Hedging methods	**MNB data**	**Bank data**	**Survey**
H3: The hedging ratio of currency risk depends on the direction of the exposure; it is higher for long foreign currency positions (against HUF).	+		-
H4: The ratio of options in the hedging of foreign-exchange risk is negligible, but increasing.	+/-		+/?
H5: The hedging ratio depends on the applied derivative (forward, option).			+
H6: The foreign-exchange risk is hedged by derivatives in the short term.		+	+
Execution of hedging	**MNB data**	**Bank data**	**Survey**
H7: The increasing volatility of the foreign exchange market increases hedging activity.	+		
H8: Hedging activity increases with the rise of the expected value of the forward hedge position.	+		+

Table 30: Results of the research on corporate risk management

Although consultations with financial experts confirmed the importance of funding liquidity in corporate risk management, 90% of the firms in the sample have no initial margin obligation and 75% of them have no obligation at all to collateralize the loss of the derivative position. However, changing financial regulations will most probably lead to a reduction in the number of clients, who have no obligation to collateralize their exposure.

The analysis of the micro and macro level data seems to confirm the model of optimal hedging; the expected value of the hedging position and the financing costs affect the optimal hedge ratio. The model offers a rational explanation for the fact of corporate over- and underhedge.

The research is to be developed further by examining a wider corporate sample containing small and medium size companies as well, so that the difference between their risk management is comparable.

The Hungarian monetary policy has changed significantly since the beginning of my research. The weakening of the forint and the cutting of its interest rate eroded the positive expected value of long forward forint positions. The other direction of further research is to investigate the effect of these changes on corporate risk management.

ANNEX I: Risk management authorities and regulations

Industry	**Regulator**
Financial Institutions	Basel Commitee (Switzerland) Office of the Supervisor of Financial Institutions (OSFI, Canada) Financial Services Authority (FSA, United Kingdom)
Insurance Companies	A.M. Best Moody's Standard & Poor's National Association of Insurance Commissioners (NAIC) Australian Prudential Regulation Authority (APRA)
General	Cadbury Report, London Stock Exchange Dey Report, Toronto Stock Exchange Australia/New Zealand Risk Management Standard KonTraG (Germany)

Source: Casualty Actuarial Society, 2003

ANNEX II: Financial derivatives hedging market risk

Financial derivatives[65] can be ordered in three groups: forwards/futures, options and the combination of forwards and options.

A *forward or futures agreement* fixes all parameters of a future exchange, so both parties are obliged to deliver according to the contract. Forwards are traded on exchanges, while forwards in over-the-counter markets.

From *hedging* perspective *forward* agreements can perfectly eliminate the risk of future price as it can be fixed at the forward rate. Forward hedge for the total exposure reduces the variance of the portfolio at risk to zero – as long as amount is not a random variable – excluding bad outcomes, but chance for profiting from favourable market movements as well.

Options are more flexible hedging instruments, providing protection against bad cases, but preserving upside potential. Disadvantage of option is the fee to be paid upfront, which makes hedging rather costly. There is another feature of options which has an essential psychological consequence. It is always the worse solutions ex post. In case of exercise forward would have the same result with no costs, and for unprofessional it can seem to be an unnecessary deal if the option expires without exercising.

The cost of options can be lowered by limiting the validity of the options, in case of *knock-in options* the option starts to live, if the spot price achieves a certain level, knock-out options however cease to exist if the spot price touches a predetermined level.

The aim of structuring - building complex products from basic derivatives - is to combine the above described advantages of forwards and options, and tailor the instrument to the special needs of the customer. An average structure consists of more options, where the option fee of the bought option(s) is financed by writing option(s). The result is a situation in which the potential profit or loss deriving from the structure can either be limited (each sold options are protected in the same amount through bought options, the difference of the strikes is the maximum to be lost) or unlimited, if the structure involves “naked” short

[65] Several textbooks deal with the pricing of derivatives, like Száz (2009).

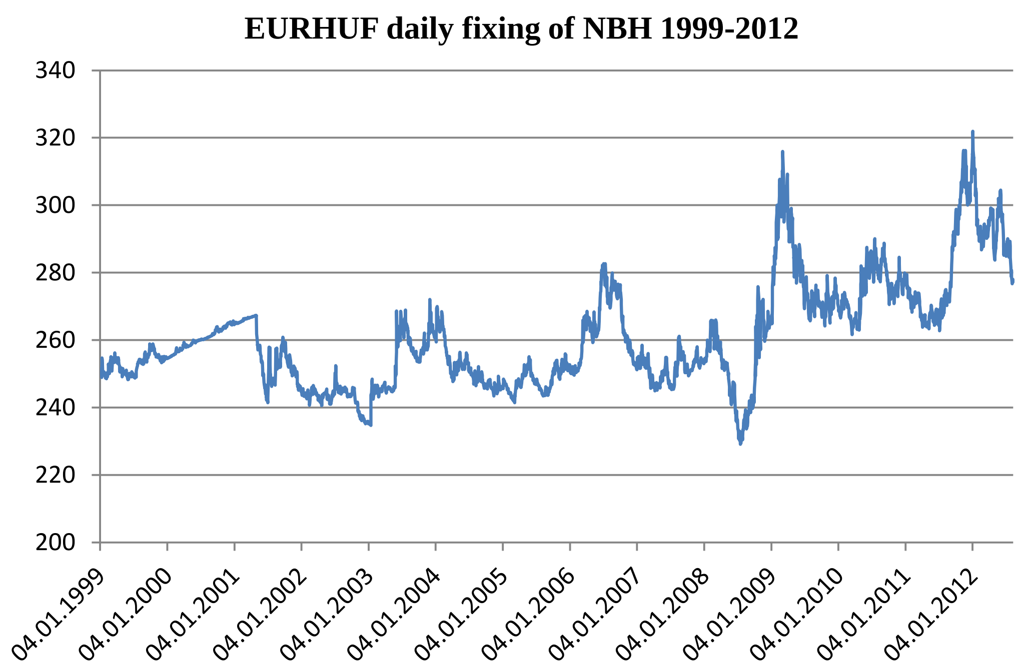
options as well. The price of the whole structure is function of the parameters of the building instruments.

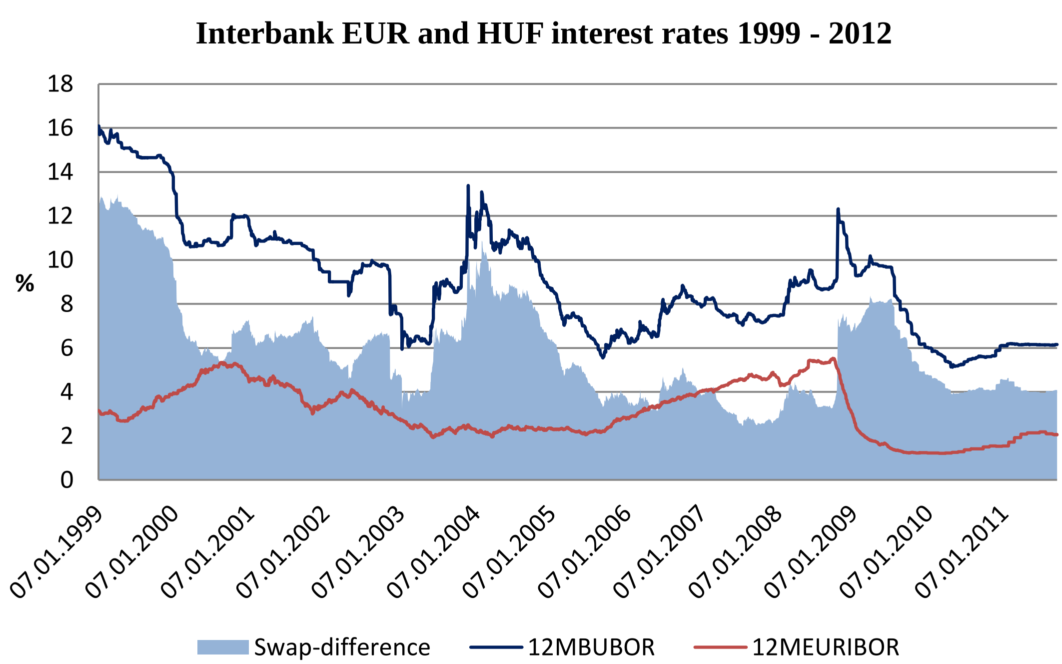
As corporations' decision-making is usually sensitive to upfront costs, the majority of the complex products are offered at zero cost, similarly to forwards, but preserving the flexibility of options, so that managers can win from market movements, if their expectation comes through. Structured derivatives may be used for managing risk actively, undertaking speculative position, in order to win. For hedging purposes only those structures are appropriate, which ensure a limited downside.

Two popular structure of the Hungarian market were average forward agreement that is series of forwards offering the same rate for several maturities. The construction as a whole is zero cost, but the individual legs have positive/negative values.

The other widespread structure consists of a bought and a sold option, for the same notional and maturity, but their types differ. For an exporting company the long option is a put and the written option is a call, fixing not a certain price, but a range for the exposure. It is also cold collar or risk reversal, and it is often structured to be zero cost, namely the fee of the bought option is the same as the price of the sold one.

ANNEX III: EUR/HUF spot rate and yields of HUF and EUR





Source: NBH, Reuters[66]

[66] 12-month BUBOR is quted since May 2002, before this date, 6-month BUBOR data are shown

ANNEX IV: Von Neumann – Morgenstern utility representation theorem

The Von Neumann and Morgenstern (1947) axioms give the necessary and sufficient conditions of the existence of the individual utility function.

Under the following axioms of the individual preferences, the expected utility theorem holds.

Completeness: the individual has well defined preferences and can always decide between any two alternatives, meaning the individual either prefers A to B, or is indifferent between A and B, or prefers B to A.

Transitivity: the individual decides according to the completeness axiom, and the individual also decides consistently, for every A, B and C lotteries, if he prefers A to B and he prefers B to C, he has to prefer A to C also.

Continuity[67]: when there are three lotteries (A, B and C) and the individual prefers A to B and B to C, then there should be a possible combination of A and C in which the individual is then indifferent between this mix and the lottery B.

Independence: two gambles mixed with a third one maintain the same preference order as when the two are presented independently of the third one.

If all these axioms are satisfied, then the individual is said to be rational and the preferences can be represented by a utility function, i.e. one can assign numbers (utilities) to each outcome of the lottery such that choosing the best lottery according to the preference amounts to choosing the lottery with the highest expected utility

[67] This axiom can be replaced by the so called Archimedean property, which requires not full equality, but it states that with the change of the weights every perference can be reproduced.

Annex V: Upper and lower bounds of optimal hedging ratio

The optimal solution has to ensure a positive profit at any price evolution. The theoretically lowest value of S_2 equals to zero. By substituting S_2=0, Equation (47) takes the following form:

$$\Pi = -c(Q) + h(F_0) + k\min\left[h\frac{(F_0 - F_1)}{1+r};0 \right] > 0 \tag{VI.1}$$

In the absence of financing cost the lower bound of the hedge ratio (*h/Q*) is the same as in the Korn-model ($h/Q > \bar{c}/F_0$).

In the presence of financing costs, we have to suppose a maximum of the price change ($\Delta F_{1max\alpha}$) as there is no theoretical upper bound of the price. Substituting it into Equation (47), the result will be the following:

$$\Pi = -c(Q) + h(F_0) + kh\frac{(\Delta F_{1\max\alpha})}{1+r} > 0 \tag{VI.2}$$

After the rearrangement of the above equation, the lower bound in Equation (51) is given.

The maximum of the hedge ratio is the level, where the financing cost and the negative value of the hedged position are counterbalanced by the realized higher operating income. Denoting the maximum of the price at maturity by $S_{2max} = F_0 + \Delta F_{2max\alpha}$, and substituting it and the maximum of F_1 into Equation (47), we get:

$$\Pi = F_0 + \Delta F_{2\max\alpha} - c(Q) + h(F_0 - F_0 + \Delta F_{2\max\alpha}) + kh\frac{(F_0 - (F_0 + \Delta F_{1\max\alpha}))}{1+r} > 0 \tag{VI.3}$$

After rearrangement and simplification we receive the upper bound of the hedge ratio in Equation (52).

ANNEX VI: Descriptive Statistics of dispersion

Standard deviation:

$$\sigma = \sqrt{E[(x - E(x))^2]} \quad \text{(VII.1)}$$

Discrete distribution: $$\sigma = \sqrt{\sum_{i=1}^{n} p_i (x_i - E(x))^2} \quad \text{(VII.2)}$$

Continuous distribution: $$\sigma = \sqrt{\int_{-\infty}^{+\infty} (x - E(x))^2 f(x) dx} \quad \text{(VII.3)}$$

Calculated from sample: $$\sigma = \frac{1}{n-1} \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2} \quad \text{(VII.4)}$$

Skewness:

$$\gamma = E\left[\left(\frac{x - E(x)}{\sigma}\right)^3\right] \quad \text{(VII.5)}$$

Discrete distribution: $$\gamma = \sqrt{\sum_{i=1}^{n} p_i \left(\frac{x_i - E(x)}{\sigma}\right)^3} \quad \text{(VII.6)}$$

Continuous distribution: $$\gamma = \sqrt{\int_{-\infty}^{+\infty} \left(\frac{x - E(x)}{\sigma}\right)^3 f(x) dx} \quad \text{(VII.7)}$$

Calculated from sample: $$\gamma = \frac{\sqrt{n(n-1)}}{n-2} \frac{\frac{1}{n}\sum_{i=1}^{n} (x_i - \bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n} (x_i - x)^2\right)^{\frac{3}{2}}} \quad \text{(VII.8)}$$

Kurtosis:

$$\beta = E\left[\left(\frac{x - E(x)}{\sigma}\right)^4\right] \qquad \text{(VII.9)}$$

Discrete distribution:
$$\beta = \sqrt{\sum_{i=1}^{n} p_i \left(\frac{x_i - E(x)}{\sigma}\right)^4} \qquad \text{(VII.10)}$$

Continuous distribution:
$$\beta = \sqrt{\int_{-\infty}^{+\infty} \left(\frac{x - E(x)}{\sigma}\right)^4 f(x)dx} \qquad \text{(VII.11)}$$

Calculated from sample:
$$\beta = \frac{(n+1)n(n-1)}{(n-2)(n-3)} \frac{\sum_{i=1}^{n}(x_i - \overline{x})^4}{\left(\sum_{i=1}^{n}(x_i - x)^2\right)^2} \qquad \text{(VII.12)}$$

In case of normal distribution the above calculated kurtosis is 3, usually it is reduced by 3, and that ratio, the excess kurtosis is used in several textbooks. When calculating it from a sample, the 3 to be subtracted is also to be corrected, it is to be multiplied by $(n-1)^2/((n-2)(n-3))$.

ANNEX VII: Analysis of forward FX positions in SPSS

SPSS output of the multivariate linear regression model of short forward FX positions (analysis in chapter 6.2.3)

Descriptive statistics

	Mean		St. dev.	Variance	Skewness		Kurtosis		Relative
	value	St. dev	value	value	value	St. dev	value	St. dev.	st. dev.
Deviza_short	.0049	.01210	.11974	.014	.617	.244	1.257	.483	0.04
EURHUF	.0012	.00282	.02796	.001	.897	.244	3.208	.483	0.04
EURUSD	.0015	.00321	.03173	.001	-.392	.244	1.029	.483	0.05
EURHUF_v_90	.0134	.01550	.15341	.024	1.848	.244	7.407	.483	0.09
EURHUF_v_30	.0537	.03858	.38193	.146	1.859	.244	5.239	.483	0.14
EURHUF_v_1Y	.0045	.01158	.11461	.013	3.950	.244	25.986	.483	0.04
EURUSD_v_30	.0072	.01506	.14906	.022	1.597	.244	3.786	.483	0.05
EURUSD_v_90	.0024	.00857	.08484	.007	.627	.244	.662	.483	0.03
EURUSD_v_1y	.0038	.00840	.08318	.007	.948	.244	2.861	.483	0.05
EURHUF_swap	.0082	.01780	.17619	.031	1.751	.244	4.411	.483	0.05
BUBOR	-.0017	.00697	.06904	.005	1.845	.244	7.625	.483	-0.03
EURIBOR	-.0027	.00659	.06523	.004	-1.246	.244	3.170	.483	-0.04
Export	.0163	.01153	.11416	.013	.231	.244	.015	.483	0.14
Import	.0124	.01005	.09949	.010	.071	.244	-.056	.483	0.13
December	.0714	.02615	.25886	.067	3.380	.244	9.621	.483	0.28

Model Summary[f,g]

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.520[a]	.271	.263	.10234	.271	36.011	1	97	.000	
2	.669[c]	.448	.437	.08949	.177	30.849	1	96	.000	
3	.753[d]	.566	.553	.07975	.118	25.886	1	95	.000	
4	.775[e]	.601	.584	.07690	.035	8.165	1	94	.005	1.777

a. Predictors: EURHUF
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Predictors: EURHUF, December
d. Predictors: EURHUF, December, EURHUF_v_30
e. Predictors: EURHUF, December, EURHUF_v_30, EURIBOR
f. Unless noted otherwise, statistics are based only on cases for which VAR00021 = 1.00.
g. Dependent Variable: Deviza_short
h. Linear Regression through the Origin

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.377	1	.377	36.011	.000[d]
	Residual	1.016	97	.010		
	Total	1.393[e]	98			
2	Regression	.624	2	.312	38.971	.000[f]
	Residual	.769	96	.008		
	Total	1.393[e]	98			
3	Regression	.789	3	.263	41.344	.000[g]
	Residual	.604	95	.006		
	Total	1.393[e]	98			
4	Regression	.837	4	.209	35.388	.000[h]
	Residual	.556	94	.006		
	Total	1.393[e]	98			

a. Dependent Variable: Deviza_short

b. Linear Regression through the Origin

c. Selecting only cases for which VAR00021 = 1.00

d. Predictors: EURHUF

e. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

f. Predictors: EURHUF, December

g. Predictors: EURHUF, December, EURHUF_v_30

h. Predictors: EURHUF, December, EURHUF_v_30, EURIBOR

Coefficients[a,b]

Model		Unstandardized Coefficients		Stand. Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	EURHUF	2.228	.371	.520	6.001	.000	.520	.520	.520	1.000	1.000
2	EURHUF	2.277	.325	.532	7.012	.000	.520	.582	.532	.999	1.001
	December	-.188	.034	-.421	-5.554	.000	-.407	-.493	-.421	.999	1.001
3	EURHUF	1.826	.303	.427	6.034	.000	.520	.526	.408	.914	1.095
	December	-.185	.030	-.415	-6.136	.000	-.407	-.533	-.415	.999	1.001
	EURHUF_v_30	.112	.022	.360	5.088	.000	.488	.463	.344	.914	1.094
4	EURHUF	2.035	.301	.475	6.763	.000	.520	.572	.441	.860	1.163
	December	-.176	.029	-.395	-6.021	.000	-.407	-.528	-.392	.987	1.013
	EURHUF_v_30	.104	.021	.336	4.900	.000	.488	.451	.319	.901	1.110
	EURIBOR	.355	.124	.193	2.857	.005	.149	.283	.186	.927	1.078

a. Dependent Variable: Deviza_short

b. Linear Regression through the Origin

c. Selecting only cases for which VAR00021 = 1.00

Collinearity Diagnostics[a,b]

Dimension		Eigenvalue	Condition Index	Variance Proportions			
				EUR/HUF	Dec.	EURHUF_v_30	EURIBOR
1	1	1.000	1.000	1.00			
2	1	1.027	1.000	.49	.49		
	2	.973	1.028	.51	.51		
3	1	1.293	1.000	.35	.00	.35	
	2	1.002	1.136	.00	.99	.01	
	3	.705	1.354	.65	.01	.64	
4	1	1.354	1.000	.32	.02	.19	.12
	2	1.117	1.101	.01	.31	.24	.29
	3	.920	1.213	.02	.66	.11	.25
	4	.609	1.492	.65	.01	.47	.34

a. Dependent Variable: Deviza_short

b. Linear Regression through the Origin

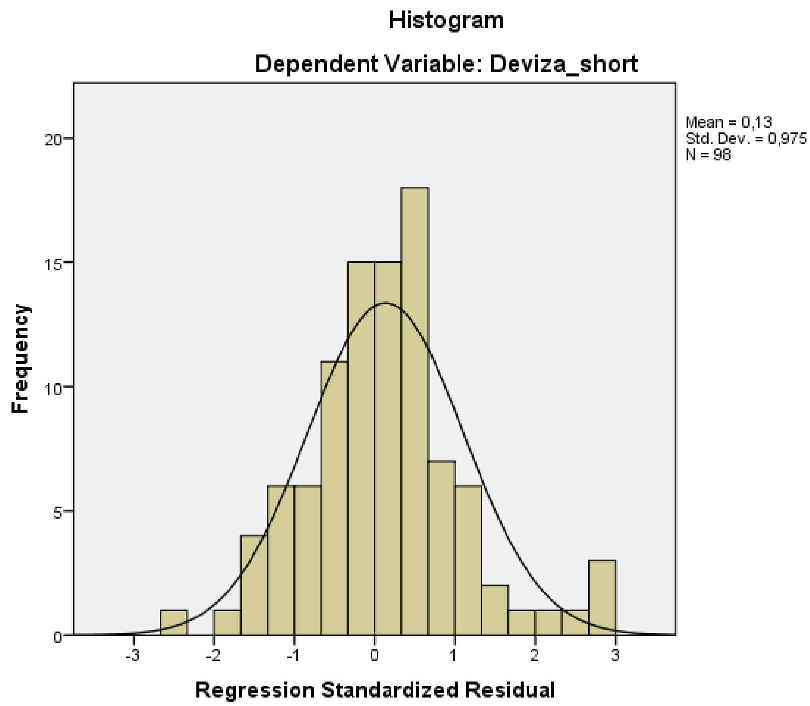
c. Selecting only cases for which VAR00021 = 1.00

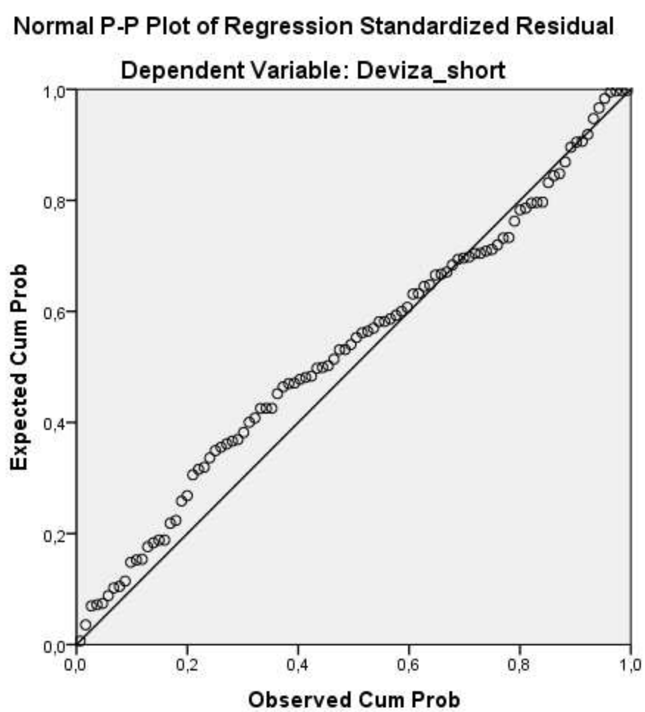
Residuals Statistics[a,b]

	VAR00021 = 1.00 (Selected)				
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.2556	.2676	-.0054	.09274	98
Std. Predicted Value	-2.697	2.944	.000	1.000	98
Standard Error of Predicted Value	.002	.041	.013	.009	98
Adjusted Predicted Value	-.2506	.2851	-.0054	.09429	98
Residual	-.19157	.22276	.01032	.07499	98
Std. Residual	-2.491	2.897	.134	.975	98
Stud. Residual	-2.505	3.016	.134	1.001	98
Deleted Residual	-.19364	.24273	.01029	.07924	98
Stud. Deleted Residual	-2.579	3.156	.138	1.020	98
Mahal. Distance	.103	27.737	4.000	5.736	98
Cook's Distance	.000	.282	.015	.041	98
Centered Leverage Value	.001	.283	.041	.059	98

a. Dependent Variable: Deviza_short

b. Linear Regression through the Origin


Histogram
Dependent Variable: Deviza_short
Mean = 0,13
Std. Dev. = 0,975
N = 98
Frequency
Regression Standardized Residual
0
5
10
15
20
-3
-2
-1
0
1
2
3


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Deviza_short
Expected Cum Prob
Observed Cum Prob
0,0
0,2
0,4
0,6
0,8
1,0

SPSS output of the multivariate linear regression model of long forward FX positions (analysis in chapter 6.2.4)

Descriptive statistics

	Mean		St. dev.	Variance	Skewness		Kurtosis		Relative
	value	St. dev	value	value	value	St. dev	value	St. dev.	st. dev.
Deviza_short	.0049	.01210	.11974	.014	.617	.244	1.257	.483	0.04
EURHUF	.0012	.00282	.02796	.001	.897	.244	3.208	.483	0.04
EURUSD	.0015	.00321	.03173	.001	-.392	.244	1.029	.483	0.05
EURHUF_v_90	.0134	.01550	.15341	.024	1.848	.244	7.407	.483	0.09
EURHUF_v_30	.0537	.03858	.38193	.146	1.859	.244	5.239	.483	0.14
EURHUF_v_1Y	.0045	.01158	.11461	.013	3.950	.244	25.986	.483	0.04
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EURUSD_v_90	.0024	.00857	.08484	.007	.627	.244	.662	.483	0.03
EURUSD_v_1y	.0038	.00840	.08318	.007	.948	.244	2.861	.483	0.05
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EURIBOR	-.0027	.00659	.06523	.004	-1.246	.244	3.170	.483	-0.04
Expot	.0163	.01153	.11416	.013	.231	.244	.015	.483	0.14
Import	.0124	.01005	.09949	.010	.071	.244	-.056	.483	0.13
December	.0714	.02615	.25886	.067	3.380	.244	9.621	.483	0.28

Model Summary[f,g]

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.566[a]	.320	.313	.10633	.320	44.230	1	94	.000	
2	.634[b]	.402	.389	.10023	.082	12.794	1	93	.001	
3	.689[c]	.475	.458	.09441	.073	12.821	1	92	.001	1.895

a. Predictors: (Constant), December

b. Predictors: (Constant), December, EURHUF

c. Predictors: (Constant), December, EURHUF, EURHUF_v_90

d. Unless noted otherwise, statistics are based only on cases for which VAR00022 = 1.00.

e. Dependent Variable: Deviza_long

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.500	1	.500	44.230	.000[c]
	Residual	1.063	94	.011		
	Total	1.563	95			
2	Regression	.629	2	.314	31.287	.000[d]
	Residual	.934	93	.010		
	Total	1.563	95			
3	Regression	.743	3	.248	27.783	.000[e]
	Residual	.820	92	.009		
	Total	1.563	95			

a. Dependent Variable: Deviza_long

b. Selecting only cases for which VAR00022 = 1.00

c. Predictors: (Constant), December

d. Predictors: (Constant), December, EURHUF

e. Predictors: (Constant), December, EURHUF, EURHUF_v_90

Coefficients[a,b]

Model		Unstandard. Coefficients		Stand.Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.029	.011		2.526	.013					
	December	-.261	.039	-.566	-6.651	.000	-.566	-.566	-.566	1.000	1.000
2	(Constant)	.032	.011		2.943	.004					
	December	-.262	.037	-.568	-7.088	.000	-.566	-.592	-.568	1.000	1.000
	EURHUF	-1.340	.375	-.287	-3.577	.001	-.282	-.348	-.287	1.000	1.000
3	(Constant)	.028	.010		2.712	.008					
	December	-.248	.035	-.538	-7.083	.000	-.566	-.594	-.535	.988	1.012
	EURHUF	-1.711	.368	-.366	-4.653	.000	-.282	-.436	-.351	.920	1.086
	EURHUF_v_90	.236	.066	.284	3.581	.001	.239	.350	.270	.910	1.099

a. Dependent Variable: Deviza_long

b. Selecting only cases for which VAR00022 = 1.00

Collinearity Diagnostics[a,b]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	December	EURHUF	EURHUF_v_90
1	1	1.289	1.000	.36	.36		
	2	.711	1.346	.64	.64		
2	1	1.302	1.000	.35	.33	.03	
	2	.994	1.145	.00	.06	.93	
	3	.704	1.359	.65	.61	.03	
3	1	1.356	1.000	.20	.09	.20	.18
	2	1.245	1.044	.14	.30	.12	.17
	3	.755	1.341	.27	.18	.51	.24
	4	.644	1.451	.39	.43	.17	.41

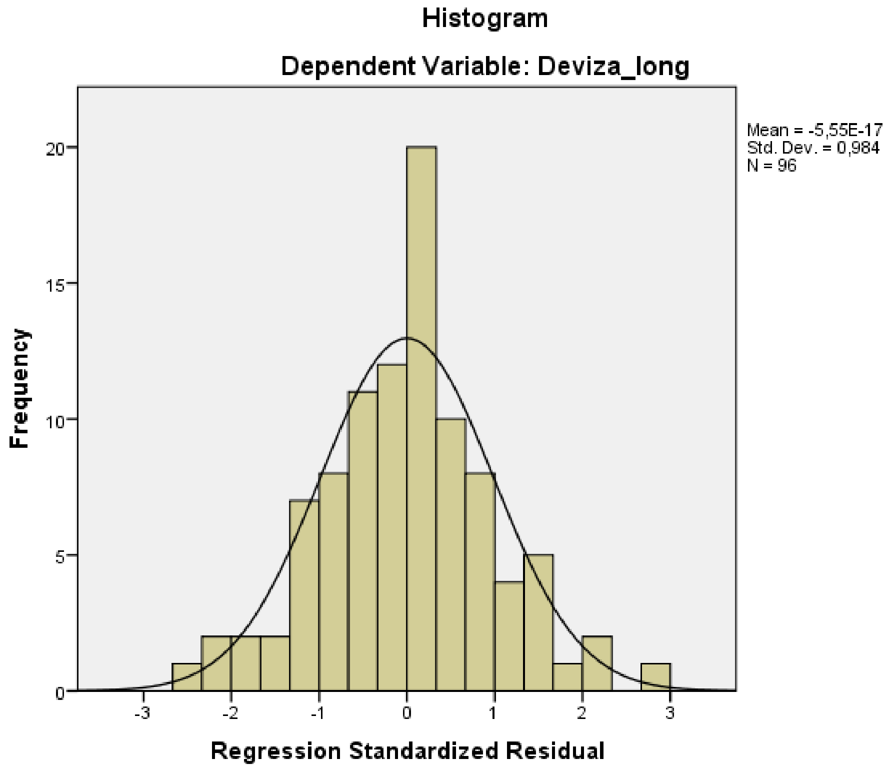
a. Dependent Variable: Deviza_long

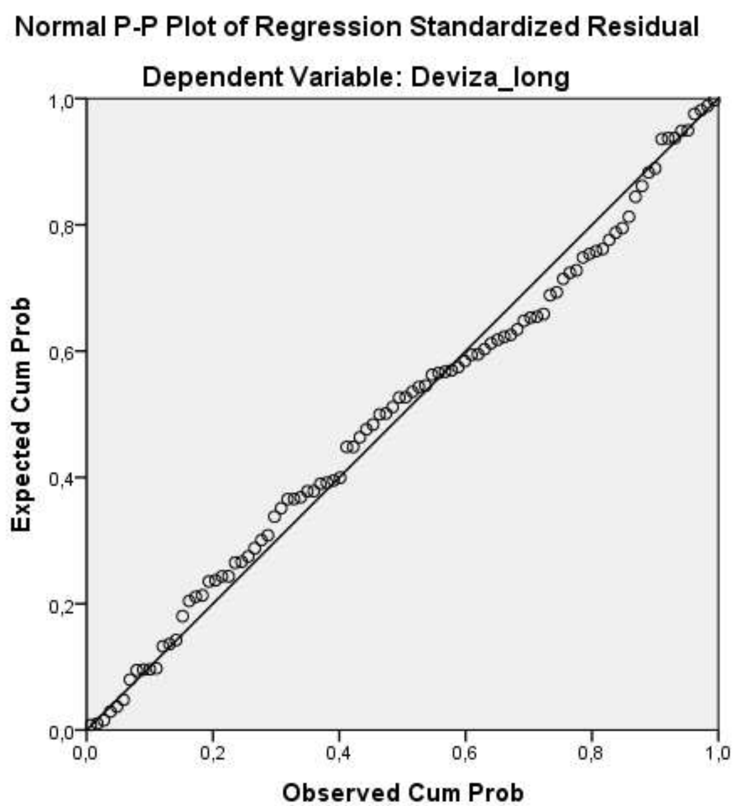
b. Selecting only cases for which VAR00022 = 1.00

Residuals Statistics[a,b]

	VAR00022 = 1.00 (Selected)				
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.2823	.1773	.0069	.08843	96
Std. Predicted Value	-3.270	1.928	.000	1.000	96
Standard Error of Predicted Value	.010	.051	.017	.008	96
Adjusted Predicted Value	-.3015	.2034	.0062	.08995	96
Residual	-.22736	.26233	.00000	.09291	96
Std. Residual	-2.408	2.779	.000	.984	96
Stud. Residual	-2.482	2.811	.003	1.011	96
Deleted Residual	-.25128	.26846	.00069	.09831	96
Stud. Deleted Residual	-2.555	2.924	.004	1.026	96
Mahal. Distance	.097	26.463	2.969	4.584	96
Cook's Distance	.000	.344	.015	.045	96
Centered Leverage Value	.001	.279	.031	.048	96

a. Dependent Variable: Deviza_long


Histogram
Dependent Variable: Deviza_long
Mean = -5,55E-17
Std. Dev. = 0,984
N = 96
Frequency
0
5
10
15
20
-3
-2
-1
0
1
2
3
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Deviza_long
Expected Cum Prob
0,0
0,2
0,4
0,6
0,8
1,0
Observed Cum Prob

ANNEX VIII: Empirical research: the survey

The questionnaire collects data to the analysis of corporate risk management with main focus on FX-risk management practice. Please indicate data or choose the appropriate answer!

I. Please fill in the table with figures of the annual report of the last three years

	2011	2010	2009
1. Total assets			
2. Equity			
3. Foreign currency denominated loans			
4. Annual revenue			
5. Export			
6. Part of operating costs arising in foreign currency			
7. Operating P/L			
8. Pre-tax P/L			

9. Number of employees ______________

10. How exchange rate movements affect corporate operating profit?
- ☐ It has no impact.
- ☐ Strengthening of forint affects negatively (exporting position).
- ☐ Weakening of forint affects negatively (importing position).

II. The questions below refer to the corporate risk management. Please choose all relevant statements!

11. What type of market risk do you face?
- ☐ Foreign exchange risk
- ☐ Interest rate risk
- ☐ Commodity risk

12. Does your company have a (written) risk management strategy?

☐ Yes ☐ No

13. If you have risk management strategy, what is the main goal of it?

☐ Reduction of the variance of corporate profit.
☐ Maximization of corporate profit.
☐ Fixing the minimum level of corporate cash-flow.
☐ Other:____

14. How does the risk management strategy of your competitors affect your risk management decisions?

☐ We do not care for the risk management of our competitors.
☐ We know the risk management strategy of our competitors, but it has no impact on our decisions.
☐ We take account of the risk management of our competitors.
☐ We adjust our risk management strategy to our competitors'.
☐ Other:____

15. How many banking relationship do you have?

☐ 1
☐ 2
☐ 2 - 5
☐ more than 5

16. What kind of contracts do you have?

☐ FX-spot conversion frame contract
☐ Forward frame contract
☐ Option frame contract
☐ ISDA contract

17. What kind of margin do you have to place to trade derivatives?

☐ We do not have such obligation.
☐ Less than 5% of the nominal amount of the transaction.
☐ 5% to 10% of the nominal amount of the transaction.
☐ More than 10% of the nominal amount of the transaction.

18. Do you have additional collateral obligation in case of negative mark-to-market value of your derivative position?

☐ We do not have to collateralize our position either initially or during the lifetime of the position.

☐ We have to place an initial margin, but we do not have any further obligations.

☐ We have to place an initial margin and also the mar-to-market loss has to be covered.

☐ We have to place an initial margin and also the mar-to-market loss has to be covered above a certain level.

19. If you have FX-risk exposure, how do you manage it?

☐ By matching the incoming and outgoing items.

☐ With financial derivatives.

☐ We do not hedge it.

☐ We do not have FX-position.

20. If you answered for the previous question not hedging the exposure, what is the reason for that? (more options can be chosen)

☐ The exposure is small, so the risk can be neglected.

☐ It is not worthy to hedge the exposure.

☐ Corporate policy forbids the usage of derivatives.

☐ We do not have bank contracts allowing derivatives trade.

☐ Accounting or other difficulties make us unable to trade derivatives.

☐ Other: ___________________________________

21. If you use derivatives hedge, what is the **maximum** maturity of the deals?

☐ less, than 3 months

☐ 3-6 months

☐ 6-12 months

☐ 12-18 months

☐ more, than 18 months

22. If you use derivatives hedge, what is the **average** maturity of the deals?

☐ less, than 3 months

☐ 3-6 months

☐ 6-12 months

☐ 12-18 months

☐ more, than 18 months

23. What proportion of the annual exposure do you hedge?

- ☐ We do not hedge.
- ☐ less, than 50%
- ☐ 50-80%
- ☐ 80-100%
- ☐ exactly 100%
- ☐ more, than 100%
- ☐ it is changing, but typically___________________%

24. If your hedging ratio differs from 100%, what is the reason for that?

- ☐ We do not hedge, because the position is too small.
- ☐ We underhedge, as the exposure cannot be forecasted precisely.
- ☐ We underhedge, as we do not have margin line enough to hedge perfectly.
- ☐ We underhedge because of the potential loss of the hedging position.
- ☐ We overhedge, as the hedging positions are usually profitable.
- ☐ Other: ____

25. What kind of derivatives do you use for hedging FX-risk?

- ☐ We do not hedge.
- ☐ Forward agreements
- ☐ Options
- ☐ Structured derivatives

26. What is the timing of hedging?

- ☐ We hedge the entire exposure once a year.
- ☐ We hedge part of the exposure once a year.
- ☐ We analyse the exposure on a regular basis, and tailor the hedge position according to that.
- ☐ We hedge only in the short term.
- ☐ We hedge if the market prices are favourable for our positions.
- ☐ Other: ____

27. Do you hedge positions exposed to interest rate risk?

☐ yes ☐ no

28. If you answered yes to the above question, how do you hedge interest rate risk?

- ☐ Our credit contracts allow the fixing of interest rate.
- ☐ We trade interest derivatives.
- ☐ Other: ____

29. If you answered no to the 27th question, what is the reason for unhedging?
- ☐ The exposure is small, so the risk can be neglected.
- ☐ It is not worthy to hedge the exposure.
- ☐ Corporate policy forbids the usage of derivatives.
- ☐ We do not have bank contracts allowing derivatives trade.
- ☐ Accounting or other difficulties make us unable to trade derivatives.
- ☐ Other: ___________________________________

30. If you trade derivatives, what kind of accounting standards do you use for bookkeeping?
- ☐ Hungarian accounting rules
- ☐ IAS or IFRS
- ☐ Other international accounting standards
- ☐ Other: ____

31. Do you apply hedge accounting?

☐ yes ☐ no

32. How often do you evaluate your derivative positions?
- ☐ Never
- ☐ Once a year to the annual report.
- ☐ Quarterly.
- ☐ Monthly.
- ☐ Every day.
- ☐ Other: ____

33. How do you measure the risk of the hedging?
- ☐ We do not measure it.
- ☐ We calculate risk measures regularly.
- ☐ Other: ____

34. Are the statements below characteristic for the company? (1-not at all, 9-absolutely)

	1	2	3	4	5	6	7	8	9
Risk management is eligible	☐	☐	☐	☐	☐	☐	☐	☐	☐
Implementation of risk management is consistent	☐	☐	☐	☐	☐	☐	☐	☐	☐
Our banks help in risk management	☐	☐	☐	☐	☐	☐	☐	☐	☐
We are conform with hedging derivatives	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hedging transactions are useful for corporate operation	☐	☐	☐	☐	☐	☐	☐	☐	☐

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