BUDAPESTI CORVINUS EGYETEM

Doctoral Program in Management and Business Administration

THESIS OUTLINE
of

Barbara Mária Dömötör

Market risk hedging under liquidity constraints

Ph.D. dissertation

Supervisor:

János SZÁZ, CSc
Professor

Budapest, 2014

Department of Finance

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1. PRELIMINARIES

1.1 The motivation and aim of the dissertation

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.

1.2 Theoretical background

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, so hedging decreases the variability of the possible 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 value of risk management can be derived from the individual utility function.

The 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. 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 does not create value either, as the individual investor can hedge under the same conditions.

In contrast with the above statement, risk management has an important role in corporate management, which can be traced back to both rational and irrational reasons. 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.

Two basic models explaining the value of corporate hedging with limited financing resources are the models of Froot et al. (1993) and Tirole (2006). In both models, corporate production and hedging is described as a two-period decision, presuming that the hedge position creates no cash-flow (except for the predetermined fees) or further risk and that bankruptcy can be avoided at the hedged price. The analysis of Froot et al. (1993) is based on interconnected corporate investment and financial decisions, while Tirole (2006) investigates the problem through agency-based considerations. Both models conclude that the costs or even the unavailability of external financing justify the rationale of hedging, as through hedging a certain level of internal financing resources can be ensured to implement the investments with positive net present value.

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.

However, 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.

The liquidity risk of the hedging position appears in the 2000's in the theoretical models. 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 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).

1.3 Research problems and hypotheses

There are three directions in the research. I build a model to describe the hedging of the risk deriving from the stochastic market price. Based on this model, foreign exchange hedging strategies are analysed through Monte Carlo simulation.

The research also contains empirical analysis that investigates the risk management practice of Hungarian firms. The empirical research focuses on three topics, in which framework the following hypotheses are analysed:

Risk awareness, managed risk types

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

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

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.

2. RESEARCH METHODOLOGY

In my own model based on the analysis of Korn (2003), the upper and lower bounds of the optimal hedging are derived, between them the hedging ratio is the function of the actual market prices and corporate specific parameters. 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. Furthermore, I analyses the effect of non-static financing costs, where the credit spread is a function of the financing need as well.

The analysis is developed in a multistage simulation model, where the hedge position needs to be financed several times during its lifetime, while the hedging position itself is required for multiple 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 also built in. 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 parameters of the model were calculated from the daily exchange rates for the period between 2006 and 2012. The expected value of the logarithmic change of the FX-rate (y_t) is zero – (1) equation –, the unconditional daily variance is 0.0000731 and the conditional variance (σ_t^2) is described by the (3) equation.

$$y_t = 0 + \varepsilon_t, \qquad \varepsilon_t \approx i.i.d.(0, \sigma_{\varepsilon,t}^2) \tag{1}$$

$$\varepsilon_t = \sigma_t z_t \qquad z_t \approx N(0,1) \tag{2}$$

$$\sigma_t^2 = 0.00000152 + 0.133741\varepsilon_{t-1}^2 + 0.84548\sigma_{t-1}^2 \tag{3}$$

The empirical research data is analysed using multivariate statistical methods. In addition to the descriptive statistics, a linear regression model is also built in order to analyses the aggregated data. In the regression model the dependent variable is the change of the total volume of the forward long and short positions, while the explanatory variables are the changes in the foreign trade positions, the EUR/HUF spot exchange rate, its volatility and the difference of the spot and forward fx-rate (swapdifference).

The empirical research contains a survey that was sent to treasury clients of a Hungarian commercial bank. The firms contacted are the largest companies in Hungary, belonging to the

Hungarian Top 500. All of the bank's active clients were approached, so the sampling method is a form of cluster sampling.

The analysis of the survey data is based on descriptive statistics, and principal component analysis is used to define the size and the risk awareness of the firms. The connection between them is investigated by means of their correlation.

3. MAIN RESULTS

3.1 Modelling the optimal hedging ratio in the presence of liquidity risk

The basis of my model is the concept of Korn (2003), who models the optimal hedging ratio by examining the trade-off between the utility achieved by the reduction of the variance and the utility loss deriving from the profit-fall due to financing costs.

My model differs from the above in that it allows a non-zero drift of the forward price process, the quantity of the production is given, and the hedging position is not adjusted during the tenor of the hedge. The optimal hedge position changes in the function of three factors that determine the corporate utility function: the risk aversion ratio of the company, the expected value of the hedge position and the financing costs deriving from the hedging itself.

The results of the model were presented at the European Conference on Modelling and Simulation, and a full paper was published in the conference proceedings:

Dömötör Barbara [2013]: *Modelling Optimal Hedge Ratio in the Presence of Funding Risk.* 27th European Conference on Modelling and Simulation, 27 May – 30 May 2013, Aalesund, Norway DOI: http://dx.doi.org/10.7148/2013-0282

In addition to the results referred to above, the thesis contains an analysis of the effect of non-static financial costs. The effect of the expected value of the hedge position proved to be more influential on the hedging ratio than the constant credit spread, but if the credit cost is a growing function of the exposure, the effect of the financing becomes dominant and leads to essential underhedging.

3.2 Simulation of foreign-exchange hedging strategies

The results based on the analysis of the currency (long euro) exposure of a Hungarian exporting company can be summarized as the following:

- Under the current (August, 2012) market circumstances and the given corporate specific parameters, the simulation 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.

- 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.
- 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, and being in long position, the hedge has no further financing need. On the other hand, the profit at maturity is lowered by the option fee and its financing costs (risk-free interest rate + credit spread). 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 other hedging strategy investigated is a structure of options. The firm buys a euro put option to protect the downside of its revenue, but simultaneously sells a euro call option to finance it (collar strategy). The strike of the put is lower, the strike of the call is higher than the forward rate, and the strikes are chosen to get a zero cost solution for the hedge. This construction ensures a similar expected utility than the forward hedge, at a higher optimal hedging ratio.

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.

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.

- The value risk of each leg grows over time, but the exposure decreases, reducing the liquidity (cash-flow) risk.
- 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.

- 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 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 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.

3.3 Empirical research: Analysis of the corporate risk management practice in Hungary

Based on the theoretical model and the empirical research, the hypotheses can be answered according to 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. 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, 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.	+		+

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.

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