An Empirical Test of Risk-Adjusted Performance Utilising Call Option Writing and Put Option Buying Hedge-Strategies

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Abstract

Continuing the research of earlier AFIR-papers, we examine return and risk of various put option buying and call option writing plans (put hedge; covered short call) based on historical simulations. With respect to shortfall risk measures we propose a test procedure to compare the risk-adjusted performance of alternative strategies.

Résumé

Poursuivant des études précédentes d'AFIR nous examinons á base des simulations historiques risque et rendement de plusieurs positions composées (put hedge; covered short call). Ayant égard aux mesures de risque de shortfall nous proposons un procédé de teste pour comparer les performances de plusieurs stratégies.

Keywords: Put Hedge, Covered Short Call, Risk-Adjusted Shortfall Performance

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1. Introduction

The use of options within the management of stock portfolios enables investors to shape the original risk-return-profile of an unprotected stock investment in a very flexible way. Particularly the combination of options with an underlying stock portfolio makes it possible to generate asymmetric return-distributions, which are unachievable by combinations of conventional stocks and bonds or only by dynamic strategies, cf. *Bookstaber/Clarke* (1984, 1985).

Various studies, especially for the American market, cf. *Merton/Scholes/Gladstein* (1978, 1982), *Trennepohl/Dukes* (1981), prove that the writing of calls (covered short call) or the buying of puts (put hedge) goes along with a reduction of risk and return, compared with the unprotected stock position. With respect to these results, there are merely first indicators for the German option market which is due to the relatively short period of stock exchange trading of options in Germany. At the Deutsche Terminbörse (DTB), stock exchange trading of options on individual stocks did not start before January 1990. The trade of options on the German stock-index (DAX) began in August 1991.

The objective of this study is to fill this gap by examining the performance of various combined stock/option positions based on historical simulations. This work focuses the so-called option-based hedge strategies to which great attention has been drawn since the papers of *Figlewski/Chidambaran/Kaplan* (1993), *Albrecht/Maurer/Stephan* (1995) and *Adam/Albrecht/Maurer* (1996). It is characteristic for option-based rollover hedge strategies that the time to maturity of the option positions is shorter than the planning horizon which consequently leads to a time series of short term option positions. The structure of the paper is as follows: In the second chapter we describe the data basis used in our study. Chapter three introduces the theoretical fundamental principles of a risk-adjusted performance measure for combined stock and option positions. Finally, chapter 4 contains the empirical results for the German market.

2. Data Basis and Strategies

As data basis for the underlying stock portfolio we used the market price at the end of each month at which the DAX was traded at the Deutsche Börse AG as well as the settlement prices of the European call and put options on the DAX for the interval from August 1991 to December 1997. The DAX is known to be a dividend- as well as subscirption-price adjusted performance-index containing the 30 „blue-chips“ with the highest market-capitalisation. Thus the historical return time series of the DAX mirrors the performance of an index of a liquid and highly diversified stock portfolio. In our study we considered the following combined stock and option strategies:

1. Put Hedge Strategy: The investor's motive to combine a stock portfolio with put options is to hedge the return of the combined position against negative price fluctuations to a certain extent, without completely renouncing excess changes of rising stock prices. Compared to the unprotected stock position, a put hedge strategy proves profitable if, at the date of maturity, the market value of the stock portfolio is below the exercise price minus the option premium paid. The put enables the investor to achieve a hedge level in terms of a minimum return receivable. On the other hand, the investor's participation in rising stock prices is reduced by the option premium paid.

These put hedge strategies are implemented technically as follows: according to an idea of *Figlewski/Chidambaran/Kaplan* (1993) on the basis of a fixed-percentage strategy, at the end of every month we buy put options at price P_t with a residual time to maturity of one resp. three months. The exercise prices X_t are corresponding to a fixed percentage rate p of the price S_t of the DAX, i.e.:

$$X_t = \frac{p}{100} \cdot S_t \quad . \tag{1}$$

We consider one in-the-money strategy (p = 106), one at-the-money strategy (p = 100) as well as one out-of-the-money strategy (p = 94). Whenever options where not available at a price wanted we choose option-contracts with an exercise price nearest to the one we wanted. The investment budget V_t available at the beginning of each period was used to buy put options as well as to invest in the underlying. The ratio of puts bought to units of the underlying in stock (hedge ratio) is supposed to be the same in every period (1:1 put hedge). The number of puts resp. the number of units in stock can be obtained according to:

$$q_t = \frac{V_t}{S_t + P_t} \quad . \tag{2}$$

At the end of every month the three month puts, having left a residual time to maturity of two months, are sold at the price of P_{t+1} and the one month puts are balanced. The value at the end of each month can be obtained by:

$$V_{t+1} = q_t \cdot (S_{t+1} + P_{t+1}) \quad . \tag{3}$$

In the case of a strategy with one month options we get $P_{t+1} = \max(0, X_t - S_{t+1})$. In sum, we have 76 maintenance-periods per strategy with corresponding one-period-returns according to:

$$R_t = \frac{V_{t+1}}{V_t} - 1 \quad . \tag{4}$$

2. Covered-Short-Call Strategy: The strategy to write calls on a given stock portfolio is very popular especially for institutional investors. One possible motive for this option strategy is to improve the return of the stock portfolio in times of low price fluctuations by earning the call option premiums (cf. *Zimmermann* 1996, p. 62). Another motive might be to reduce negative price movements of the stock portfolio through the collected premiums. Since any declines in prices - independent of their altitude - are reduced by the collected premium, the effectiveness of a protection is relatively good in times of low declines in prices but only moderate whenever declines in prices are strong. The disadvantage of a covered-short-call strategy lies in the fact that it enables the investors to participate in rising stock prices only up to a limit given by the exercise price of the call.

The technical implication of this strategy is to sell calls with residual times to maturity of one resp. three months at a price of C_t at the beginning of every month. The revenue of the sale is re-invested in the underlying. Like the put hedge according to (1) the exercise price equals a fixed percentage rate p of the price S_t of the underlying. Again we consider one in-the-money strategy ($p = 94$), one at-the-money strategy ($p = 100$) as well as one out-of-the-money strategy ($p = 106$). Here, again, we choose option-contracts with an exercise price nearest to the one we wanted whenever options where not available at a price wanted. The number of units of the underlying was supposed to equal the number of calls sold in every period. To realise this a number of

$$q_t = \frac{V_t}{S_t - C_t} \tag{5}$$

calls were sold resp. DAX-units were bought. At the end of every month the three-month calls, having left a residual time to maturity of two months, are balanced and so are possible losses of the one month options. The value at the end of each month can be obtained by:

$$V_{t+1} = q_t \cdot (S_{t+1} - C_{t+1}) \quad . \tag{6}$$

For the strategy with one month options we get $C_{t+1} = \max(S_t - X_{t+1}, 0)$. The corresponding 76 monthly returns for the test period we get according to (4).

The following table lists all strategies. The numbers in brackets indicate the average exercise prices realised during the test period as well as their dispersions.

TABLE 1 LIST OF STRATEGIES	
N°	Strategy
1	**Write one month covered short calls** in-the-money (94.25% / 0.79%) at-the-money (100.02% / 0.40%) out-of-the-money (105.33% / 1.07%)
2	**Write three months covered short calls** in-the-money (94.64% / 1.13%) at-the-money (99.94% / 0.34%) out-of-the-money (105.15% / 1.18%)
3	**Put hedge using one month puts** in-the-money (105.31% / 1.10%) at-the-money (100.02% / 0.40%) out-of-the-money (94.25% / 0.79%)
4	**Put Hedge using three months puts** in-the-money (105.13% / 1.17%) at-the-money (99.94% / 0.34%) out-of-the-money (94.63% / 1.13%)

3. Criteria for an analysis of the strategies

In literature (cf. *Adam/Maurer/Möller* 1996) there has been little discussion about the expected return E(R) as an adequate measure of chance of the return R of a specific investment-strategy. In contrast, traditional measures of risk such as the variance Var(R) or the standard deviation $\sigma(R) = \sqrt{\mathrm{Var}(R)}$, are criticised to an increasing extent (cf. *Clarksen* 1990, *Sortino/van der Meer* 1991). The starting-point of the criticism of these measures focuses directly on the definition of the variance

$$\mathrm{Var}(R) = \mathrm{E}[(R - \mathrm{E}(R))^2] \tag{7}$$

as the average quadratic deviation of all possible returns from the expected return. Possible deviations from the expected value both negative and positive are measured as risk. Normally, only negative deviations from the expected value or a certain reference value represent a risk economically relevant for the investor. Positive deviations are, on the contrary, desired and therefore represent the chance of an investment. The statistical nature of the return-variance resp. the standard-deviation of the return is rather a fluctuation measure than an adequate measure of risk. In case of sufficient symmetric risk-return-profiles, these measures can approximate the risk in an acceptable way. However, combined stock/option strategies typically generate asymmetric, skewed risk-return-profiles due to their specific pay-off-characteristics. Looking at the put hedge for example, the downside risk of the investor is limited to an absolute extent. On the other hand, the investor participates in increases of the prices of the underlying object to an unlimited extent, only reduced by the option premium.

Therefore there is a need to measure this basically asymmetric nature of combined stock/option strategies with adequate risk measures, which only involve the negative deviations of the return expected by the investors. In literature (cf. *Hogan/Warren* 1974, *Adam/Albrecht/Maurer* 1996), attention has been drawn to the class of ***shortfall risk measures***. Shortfall-risk denotes the realisations below a exogenously given target return over a specific period of time. A natural candidate for the target return of a financial investment is the riskless interest rate r_f. Shortfall risk measures of the return R can be obtained by using the n-th lower partial moment (cf. *Albrecht* 1994):

$$\mathrm{LPM}_n(R, R_f) = \mathrm{E}[\max(R_f - R, 0)^n] \quad . \tag{8}$$

Only realisations of R below the target return are taken into consideration when using these risk measures. For the case $n = 1$ we get the shortfall expectation and for the case $n = 2$ we get the shortfall variance resp. the shortfall standard-deviation as the square-root of the shortfall variance.

Depending on the type of option (put/call) and the exercise price (in-, at-, out-of-the-money) the risk-return-profile of the option strategy is changing compared to the unprotected stock position. To be able to compare the different option strategies among each other, it is necessary to fix an appropriate benchmark. The return R_O of the option strategy in question relative to the return of a suitable benchmark R_B can be obtained by:

$$R_D = R_O - R_B \quad . \tag{9}$$

The benchmark portfolio should be composed of the underlying stock position and a riskless investment. The investment expenditure is fixed according to the guideline that the risk of the benchmark portfolio is to be the same as the risk of the option strategy. Be x the share invested in the underlying stock position with return R_S and $(1 - x)$ the share spent for the riskless investment, we obtain the return of the benchmark portfolio:

$$R_B = xR_S + (1 - x)R_f \quad . \tag{10}$$

Be $\sigma(R_S)$ the volatility of R_S we get $\sigma(R_B) = x\sigma(R_S)$. If the volatility of the benchmark has to match the volatility of the option strategy $\sigma(R_O)$, x is to specify according to:

$$x = \frac{\sigma(R_O)}{\sigma(R_S)} =: x_\sigma \tag{11}$$

For the shortfall expectation of the benchmark we similarly get $\text{LPM}_1(R_B, R_f) = \text{E}[\max(R_f - R_B, 0)] = \text{E}[\max(R_f - xR_S - (1-x)R_f, 0)] = x\text{LPM}_1(R_S, R_f)$. If the share invested in the stock position is fixed according to:

$$x = \frac{LPM_1(R_O, R_f)}{LPM_1(R_S, R_f)} =: x_{LPM_1} \tag{12}$$

then the shortfall expectation of the benchmark matches the shortfall expectation of the option strategy. The same is true for the shortfall standard-deviation $\text{LPM}_2(R_B, R_f)^{½} = \text{E}[\max(R_f - R_B, 0)^2]^{½} = \text{E}[\max(R_f - xR_S - (1-x)R_f, 0)^2]^{½} = x\text{LPM}_2(R_S, R_f)^{½}$. Consequently, x is to be fixed according to:

$$x = \frac{LPM_2(R_O, R_f)^{1/2}}{LPM_2(R_S, R_f)^{1/2}} =: x_{LPM_2} \tag{13}$$

to get an identical risk position concerning the shortfall standard-deviation. The difference between the expected return of the option position and of the benchmark can be determined by:

$$E(R_D) = E(R_O) - xE(R_S) - (1-x)R_f \quad , \tag{14}$$

with x being fixed according to (11), (12) or (13), depending on selected the risk measure. In efficient markets, it makes no difference whether the risk-return-profile is managed by a combined stock/option position of by a risk-equivalent portfolio consisting of a stock and a riskless investment.

4. Empirical Results

4.1. Risk and Return of the Strategies

Starting-point of the statistical estimation of the considered measures of risk resp. return is the sequence R_t ($t = 1, \ldots, T$) of monthly returns of the various strategies in table 1. In case the $\{R_t\}$ would be an independent and identically (according to R) distributed sequence of random variables the sample estimators

$$\bar{R} = \frac{1}{T}\sum_{t=1}^{T} R_t \tag{15}$$

and

$$\hat{\sigma}^2 = \frac{1}{T-1}\sum_{t=1}^{T}(R_t - \bar{R})^2 \tag{16}$$

are distribution free and unbiased estimators of E(R) and Var(R). Using the monthly FIBOR (reported by the Deutsche Bundesbank) as the riskless target return $R_{f,t}$ we estimate the Lower Partial Moments according to:

$$L\hat{P}M_n(R_t, R_{f,t}) := \frac{1}{T}\sum_{t=1}^{T}\max(R_{f,t} - R_t, 0)^n. \tag{17}$$

In case of independent and identically distributed R_t expression (17) gives a distribution free and unbiased estimator of the Lower Partial Moments. The cases $n = 1, 2$ give the corresponding estimators for the risk measures shortfall expectation and shortfall variance.

Table 2 contains the values of the average return and the risk measures for the unprotected DAX-portfolio as a standard of comparison.

TABLE 2 PERFORMANCE STATISTICS OF THE DAX-PORTFOLIO (in % p.m.)	
$\overline{R}$	1.252
$\hat{\sigma}$	4.137
$L\hat{P}M_1$	1.316
$\sqrt{L\hat{P}M_2}$	2.875

Table 3 presents a summary of the put option strategies:

TABLE 3 PERFORMANCE STATISTICS OF PUT HEDGE STRATEGIES (in % p.m.)			
one month put			
strategy	out-of-the-money	at-the-money	in-the-money
$\overline{R}$	1.038	0.660	0.173
$\hat{\sigma}$	3.755	2.613	1.248
$L\hat{P}M_1$	1.276	0.926	0.564
$\sqrt{L\hat{P}M_2}$	2.300	1.531	0.949
three months put			
strategy	out-of-the-money	at-the-money	in-the-money
$\overline{R}$	1.013	0.894	0.721
$\hat{\sigma}$	3.756	2.812	1.891
$L\hat{P}M_1$	1.279	0.964	0.577
$\sqrt{L\hat{P}M_2}$	2.510	1.511	0.826

Both risk and return are reduced in all option hedge plans compared to the buy and hold returns of the unprotected index portfolio. Furthermore, a higher level of protection is corresponding to a lower average return as well as lower risk measures. Remarkably, in case of in-the-money strategies with one month puts, the return is even below the average money market return of 0.466% p.m. When comparing the risk-return-profiles concerning the residual time to maturity one recognises that in case of out-of-the-money puts the one month strategy has a higher return as well as a lower risk than the three month strategy. By measuring risk only with the shortfall standard-deviation results for at- and in-the-money strategies the inverse phenomenon.

Return characteristics of covered short call option plans are presented in table 4:

TABLE 4
PERFORMANCE STATISTICS OF COVERED SHORT CALL STRATEGIES (in % p.m.)

one month call			
strategy	out-of-the-money	at-the-money	in-the-money
$\bar{R}$	1.309	0.813	0.403
$\hat{\sigma}$	3.711	2.411	1.258
$L\hat{P}M_1$	1.207	0.771	0.356
$\sqrt{L\hat{P}M_2}$	2.716	2.046	1.180
three months call			
strategy	out-of-the-money	at-the-money	in-the-money
$\bar{R}$	0.978	0.720	0.582
$\hat{\sigma}$	3.546	2.398	1.480
$L\hat{P}M_1$	1.196	0.788	0.475
$\sqrt{L\hat{P}M_2}$	2.590	1.910	1.148

Compared to the unprotected DAX-portfolio, we notice a risk reduction for all variation of covered short calls. Regardless the selected residual time to maturity and the risk measure considered, out-of-the-money strategies are riskier than at-the-money strategies, which again are riskier than in-the-money strategies. Again, as in case of the put hedge strategies, we notice a trade-off between an increasing level of protection and the average return. Out-of-the-money strategies with a residual time to maturity are the exception to rule: in these cases the return was higher compared to the unprotected stock portfolio.

4.2. Statistical Evaluation of Strategy Performance

Different risk-return-profiles of the strategies considered make a comparison of the performances more difficult. Therefore it is not possible to identify general characteristics of dominance. Risk-adjusted performance measures, like for example the *Sharpe-* or the *Sortino*-ratio, are only descriptive; information about their statistical significance are problematic. For example, the z-statistic, developed by *Jobson/Korkie* (1981), concerning the difference in Sharpe-ratios between various strategies assumes normally distributed returns. However, this assumption is not fulfilled by option strategies since their pay-off structure is asymmetric. Furthermore, there are no existing statistical test for the performance measures of *Sortino*.

The idea of the performance-analysis presented in this paper is to compare the average return of the various option strategies with the corresponding risk-equivalent buy-and-hold benchmark portfolios. The benchmark portfolio consist of the underlying DAX-portfolio and a riskless money market investment. The percentage invested in the stocks for the individual benchmark are determined according to equations (11) to (13). Therefore we used the estimated risk measures for the DAX-portfolio given in table 2 as well as for the option strategies given in tables 3 and 4. Afterwards, we calculated the differences between the return of the option strategies considered and the corresponding risk-equivalent benchmark according to $R_{D,t} = R_t - R_{B,t}$ for each of the 76 month of the test-period. The generated time series was used to test the null hypothesis

$$H_0\text{: } E(R_D) = 0 \text{ against}$$
$$H_{11}\text{: } E(R_D) < 0 \text{ resp. } H_{12}\text{: } E(R_D) > 0$$

As soon as H_0 can be rejected in favour of H_{11}, the benchmark has the same risk but a higher return compared to the corresponding option strategy. As soon as H_0 is rejected in favour of H_{12}, the option strategy has the same risk but a higher return than the benchmark portfolio.

The signed ranks test of *Wilcoxon* is a formal test-procedure that does without the assumption of a normal distribution hypothesis (cf. *Bünig/Trenkler* 1978, pp. 109 - 117). The following table indicates the average return-differences between the put hedge strategies considered and the corresponding benchmark as well as the test statistics, which follow a standard normal distribution.

TABLE 5
DIFFERENCES BETWEEN THE RETURN OF PUT HEDGE STRATEGIES AND A BENCKMARK PORTFOLIO

one month put			
Strategy	out-of-the-money	at-the-money	in-the-money
$\overline{R}_{D,\sigma}$	-0.142 (3.45)**	-0.302 (2.51)**	-0.531 (3.60)**
$\overline{R}_{D,LPM_1}$	-0.192 (6.34)**	-0.382 (3.35)**	-0.638 (3.64)**
$R_{D,\sqrt{LPM_2}}$	-0.114 (2.26)*	-0.219 (1.64)	-0.519 (3.59)**
three months put			
Strategy	out-of-the-money	at-the-money	in-the-money
$\overline{R}_{D,\sigma}$	-0.021 (0.97)	0.002 (1.00)	-0.031 (1.08)
$\overline{R}_{D,LPM_1}$	-0.027 (1.18)	0.011 (0.97)	0.001 (0.89)
$R_{D,\sqrt{LPM_2}}$	0.027 (0.22)	0.081 (0.03)	0.040 (0.68)

* (**) are significantly relevant on the 5% (1%) level, *Wilcoxon* test statistics in brackets

The empirical results in table 5 show that put hedges with a residual time to maturity of one month only in all cases have a lower return than their risk-equivalent benchmark-portfolio. And what is more, with only one exception all differences between the return of the option strategy and the benchmark are statistically significant. The same is true for a risk-adjustment with the shortfall volatility. But the differences in returns are in no case statistically relevant. One reason for the bad performance of hedge-strategies with one month puts might be the decay of the current market value of options, which is relatively high at the end of the time to maturity.

Table 6 contains the average differences of returns between covered short call strategies and the corresponding benchmarks as well as the test statistics.

TABLE 6 DIFFERENCES BETWEEN THE RETURN OF COVERED SHORT CALL STRATEGIES AND A BENCKMARK PORTFOLIO			
one month call			
strategy	out-of-the-money	at-the-money	in-the-money
$\overline{R}_{D,\sigma}$	0.127 (-3.68)**	-0.111 (0.03)	-0.302 (2.30)*
$\overline{R}_{D,LPM_1}$	0.122 (-3.68)**	-0.113 (0.04)	-0.277 (2.16)*
$R_{D,\sqrt{LPM_2}}$	0.101 (-4.08)**	-0.212 (0.40)	-0.386 (2.43)*
three months call			
strategy	out-of-the-money	at-the-money	in-the-money
$\overline{R}_{D,\sigma}$	-0.025 (-1.14)	-0.109 (0.18)	-0.108 (0.64)
$\overline{R}_{D,LPM_1}$	-0.027 (-1.14)	-0.101 (0.08)	-0.098 (0.57)
$R_{D,\sqrt{LPM_2}}$	-0.075 (-0.56)	-0.179 (0.68)	-0.144 (0.93)

* (**) are significantly relevant on the 5% (1%) level, *Wilcoxon* test statistics in brackets

With any measure for the risk-adjusted performance, the out-of-the-money call strategies with one month's time to maturity perform a significantly higher average return than the benchmark portfolio. The inverse phenomenon can be recognised applying at- resp. in-the-money calls. But the negative return-differences are only significant in the in-the-money case. The use of covered calls with a residual time to maturity of three months always proved to be unfavourable (but not significantly) compared to a risk-equivalent hedge strategy with money market instruments.

5. Conclusion

The objective of this paper was to study the risk-return-profile of several popular option-based hedge-strategies of stock portfolios on the basis of a historical simulation. To quantify the risk, we used shortfall risk measures in addition to the standard deviation as the traditional risk measure. We demonstrated that the put hedge as well as the covered short call strategies enabled a risk-reduction compared to the unprotected stock investment. But in general, the risk-reduction was won at lower returns. A option strategy superior to all others was not crystallise. A traditional alternative to hedge a stock portfolio is to add money market investments. A comparison of the performance of option strategies with the performance of money market investments did not prove a systematic superiority of on of these alternatives. These results are consistent to the hypothesis that in efficient financial markets there is no optimal strategy for all investors.

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