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# A study on the efficiency of the market for Dutch long-term call options

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The efficiency of the market for 5-year call options which are traded on the European Options Exchange in Amsterdam is investigated. Both delta, delta-vega and delta-gamma neutral arbitrage portfolios are studied. No serious inefficiencies in the market for long-term call options are detected. This result is in line with previous studies on different kinds of call options and warrants. The results for the delta-vega and delta-gamma neutral arbitrage strategies differ from the results of the simple delta-neutral strategies in two ways: they lead to positive results more often, but the variance of these results is also larger.

*Keywords*: market efficiency, long-term call options, arbitrage, hedging

## 1. INTRODUCTION

In this paper we study the efficiency of the market for Dutch long-term call options. These call options, which have a maturity of 5 years, were introduced in October 1986 on the European Options Exchange (EOE) in Amsterdam. They are contingent on the shares of five large Dutch multinationals (Akzo, KLM, Philips, Royal Dutch and Unilever). At the time of the introduction, these options were unique, because call options traded on other option exchanges had a maximum maturity of only 9 months.[1] Despite their uniqueness, until now only little empirical research has been published with regard to the Dutch long-term call options. Veld and Verboven (1995) have compared the prices of these call options with the prices of equity warrants contingent on the same stock. After comparing implied standard deviations of the call options and the warrants they concluded that the warrants are (to a large extent) overvalued

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[1] In 1990 the Chicago Board of Options Exchange (CBOE) also introduced call options with a maximum maturity of 3 years. They are often referred to as LEAPS (Long-term Equity-Anticipation Securities), see Johnson and Giaccotto (1995, p. 527).

relative to the long-term call options. In this paper we test the efficiency of the market for Dutch long-term call options (from now on DLTCs). We do this by studying the possibility of acquiring arbitrage profits by creating positions with DLTCs contingent on the same stock, but with different exercise prices and maturities, which are neutral with respect to several risk factors.

The methodology we use is based on the standard methodology for testing option market efficiency. The first study in this field was carried out by Black and Scholes (1972). They tried to create a risk-free position by buying (selling) options that were undervalued (overvalued) relative to their model and selling (buying) delta shares of the underlying stock. They tested whether the return on this position was larger than the risk-free rate of return. In their study this proved to be the case, thereby indicating inefficiencies on the over-the-counter market. However, when transaction costs were taken into account, possible arbitrage profits quickly disappeared. Galai (1977) repeated the Black–Scholes tests on options traded on the Chicago Board of Options Exchange (CBOE). He first carried out an *ex post* test. This test was performed under the assumption that trading at the closing price on day $t$, based on a trading rule that was decided by the same price, was possible. Galai (1977) found significant positive arbitrage profits. However, these arbitrage profits disappeared when a 1% transaction cost was imposed. In an *ex ante* test, the execution of trading was delayed by one day. On day $t$ it was decided whether the option was over or undervalued and the hedge ratio was calculated. The hedge was established on day $t+1$ and liquidated on day $t+2$. He found evidence of arbitrage profits, but these were significantly lower than in the *ex post* test. The *ex ante* profits also disappeared when transaction costs were considered. Galai (1977) was also the first to suggest a spread strategy. This strategy consists of a long position in one option and a short position in another option on the same underlying stock. Galai's spread results were in line with his earlier results.[2]

In their paper Chen and Johnson (1985) argued that, given that the market price deviates from the model price, the Black–Scholes technique only produces a riskless hedge if the options are held until maturity. If the option position is to be revised more frequently, an alternative hedge ratio has to be used. Such an alternative hedge ratio is derived in their paper. Lauterbach and Schultz (1991) who study the efficiency of the US market for equity warrants, use both the Black–Scholes and the Chen–Johnson hedge ratios in order to create riskless stock-warrant hedges. They find positive abnormal returns for an *ex post* strategy and lower, but still positive, abnormal returns, for an *ex ante* strategy. They find that the results for the Black–Scholes and the Chen-Johnson hedge ratios are roughly the same. When making corrections for transaction costs they conclude that only floor traders are able to make arbitrage profits. These results are important for this research, because Lauterbach and Schultz (1991) study equity warrants which, like DLTCs, have long maturities. Finally, Wei (1994) who

[2] Other studies on options market efficiency were carried out by Chiras and Manaster (1978) and Blomeyer and Klemkosky (1983). Phillips and Smith (1980) present a correction for transaction costs on the results of Chiras and Manaster (1978). See Galai (1983) for a review of efficiency studies.

studies Nikkei put warrants, also finds that the market for these long-term contracts is efficient if *ex ante* tests and transaction costs are considered.

All the above mentioned studies limit themselves to delta neutral hedges. However, a delta neutral portfolio is not entirely risk-free. For a portfolio to be really risk-free, the change of the value of the portfolio should also be immune with regard to the underlying asset's volatility (vega), the delta (gamma), the passage of time (theta) and the riskless interest rate (rho). In this paper we will limit ourselves to delta-vega and delta-gamma neutral hedges. The reason is that, after a portfolio is delta neutral, its vega and gamma are considered to be most important (see Hull, 1997, p. 331).[3] The analysis in this paper can easily be extended to, for example, delta-theta, delta-rho, delta-gamma-vega hedges and so on.

The most important empirical findings in this paper can be summarized as follows. The delta neutral trading strategy gives results which are in line with the results in the literature. Positive arbitrage profits can be found for *ex post* strategies without transaction costs. However, the profits disappear when transaction costs and/or *ex ante* hedges are considered. The results for delta-gamma and delta-vega neutral strategies do not deviate much from the results of the delta neutral strategy. The delta-gamma and delta-vega neutral strategies lead more often to positive results. However, the profits also seem to be more variable. Therefore, we cannot detect any serious inefficiencies in the market for DLTCs.

The remainder of this paper is organized as follows. In Section 2 the methodology and data description are presented. Our main results are presented in Section 3. The paper is concluded in Section 4, where a summary and some conclusions are presented.

## 2. METHODOLOGY AND DATA DESCRIPTION

### 2.1 Data description

In this study we use daily closing prices of long-term call options for the period 1 April to 30 September for the years 1990 and 1991. For each stock, each year in October one new series of call options is introduced with an exercise price close to the then prevailing stock price. Trading in long-term call options started in 1986. Therefore in October 1991 the first series expired. In Appendix 1 the long-term call options outstanding in our research period (with their respective exercise prices, introduction months and expiration dates) are presented. In our research we do not use all the available series, since we always have four options series, while at most three are needed for our hedging strategies. Although the interest here is in long-term call options, we do not want to lose too many observations because of liquidity problems. Therefore, we always combine one or two long-term options with the shortest-to-maturity options which are the most actively traded. In the delta-gamma and delta-vega neutral

[3] Clewlow *et al.* (1995) also discuss the use of delta-vega and delta-gamma hedges in a different context. See also Fung (1995) for a comment on their analysis.

trading strategies we use the shortest-to-maturity and the two longest-to-maturity options. Because we want to focus on *long*-term call options, we define the shortest-to-maturity option as the option which, at the time it is considered, has a maturity between 1 and 2 years. In 1990, we use the 1986 series as the shortest-to-maturity options. These options had a remaining time to maturity of approximately 1½ years on 1 April 1990.[4] In 1991 we use the 1987 series as the shortest-to-maturity options. The longest-to-maturity options in 1990 are the 1988 and 1989 series. These options had a remaining time to maturity of approximately 3½ and 4½ years, respectively, on 1 April 1990.[5] In 1991 we use the 1989 and 1990 series as the longest-to-maturity options.

In Table 1 the number of long-term call options investigated in each year is included. If on a certain day there is no trading in an option the observation is excluded from the sample. This is also the case if the option price is less than

**Table 1.** Number of observations for each long-term call option during each research interval

| | Number of observations used in our study | |
|---|---|---|
| Long-term call option | 1 April to 30 September 1990 | 1 April to 30 September 1991 |
| Akzo 1986 | 123 | – |
| Akzo 1987 | – | 38 |
| Akzo 1988 | 116 | – |
| Akzo 1989 | 120 | 119 |
| Akzo 1990 | – | 119 |
| KLM 1986 | 123 | – |
| KLM 1987 | – | 42 |
| KLM 1988 | 72 | – |
| KLM 1989 | 107 | 64 |
| KLM 1990 | – | 121 |
| Philips 1986 | 121 | – |
| Philips 1987 | – | 104 |
| Philips 1988 | 124 | – |
| Philips 1989 | 120 | 125 |
| Philips 1990 | – | 126 |
| Royal Dutch 1986 | 121 | – |
| Royal Dutch 1987 | – | 124 |
| Royal Dutch 1988 | 118 | – |
| Royal Dutch 1989 | 122 | 126 |
| Royal Dutch 1990 | – | 105 |
| Unilever 1986 | 122 | – |
| Unilever 1987 | – | 109 |
| Unilever 1988 | 99 | – |
| Unilever 1989 | 120 | 118 |
| Unilever 1990 | – | 84 |

[4] The expiration date of these options is 18 October 1991, see Appendix 1.

[5] The respective expiration dates of these options are 15 October 1993 and 21 October 1994, see Appendix 1.

the intrinsic value. The reason for excluding the last mentioned category of options is that these observations are probably caused by the fact that the data on the stock and option exchanges are not perfectly synchronous.[6]

Information on the call option prices, the prices of the underlying stock, the exercise prices and the maturities, is derived from Datastream. The only exceptions are the call option prices of the series issued in 1986. At the time we started this research these series were no longer available in Datastream, therefore this information had to be taken from the Dutch financial newspaper *De Officiële Prijscourant*, an official publication of the stock and options exchanges in Amsterdam. The riskless interest rate used to calculate the model prices of the options, is estimated as the yield on government bonds with a maturity of 3 to 5 years, which is also derived from *De Officiële Prijscourant.*

For the period from 1 April to 30 September in year $t$, the dividend yield is taken to be the ratio of the dividend paid in the period 1 April of year $t$-1 to 31 March of year $t$, over the average stock price in that period, which was estimated as the average of the closing stock prices realized on the first trading day of each month.

In this study we investigate whether arbitrage possibilities exist if the model price of option $i$ ($C_{i,t}^{\text{mod}}$) differs from its market price ($C_{i,t}^{\text{mkt}}$). We calculate model prices using the binomial tree of Cox *et al.* (1979). By doing this we assume that the model of Black and Scholes (1973) for the stock price process holds and we take into account dividend payments and early exercise possibilities.

As a measure of the volatility we use the average of the implied volatilities of each option over the last three trading days. This measure ensures the calculated option prices do not depend on one estimated volatility only, which might cause spurious arbitrage profits. At the same time our measure still uses the most recent information in the market.

## 2.2 Methodology

### *Delta hedges*

In this paper, we use the spread strategy as originally suggested by Galai (1977). We start by using simple delta-neutral trading strategies. The relative mispricing between DLTCs $A$ and $B$ can be detected by comparing the ratio of model prices with the ratio of market prices. These ratios are based on the closing prices of the stock and the options. More precisely, the methodology is as follows. If

$$\frac{C_{A,t}^{\text{mod}}}{C_{B,t}^{\text{mod}}} > \frac{C_{A,t}^{\text{mkt}}}{C_{B,t}^{\text{mkt}}}$$

then we buy DLTC $A$ and sell $B$. In order to make the trading strategy neutral in delta, we take a long position of 1 contract in option $A$ and a short position of $\Delta_A/\Delta_B$ contracts in option $B$. Here $\Delta_i$ is the delta of option $i$. If the relationship

[6] See Evnine and Rudd (1985).

between the ratios is the reverse, we sell one contract DLTC *A* and buy $\Delta_A/\Delta_B$ contracts *B*.

The efficiency of the market for DLTCs is analysed using both an *ex post* and an *ex ante* strategy. In the *ex post* strategy the mispricing is observed using the closing prices at day *t* and the portfolio of options is established at these same prices. The portfolio is liquidated at the market prices on day $t+1$. In the *ex ante* strategy the mispricing is observed using the closing prices at day *t* and the portfolio of options is established at day $t+1$. The portfolio is then liquidated at the market closing prices on day $t+2$.

Both the *ex post* and the *ex ante* strategies are carried out with and without transaction costs. In the case that transaction costs are taken into account, we assume a fixed one-way trading cost of *f* 1.00 per option contract (one contract is 100 options).[7] Thus, in total we distinguish four delta-neutral trading strategies.

This procedure will be carried out for the two sample periods. We use for options *A* and *B* the longest-to-maturity and the shortest-to-maturity options, respectively. Thus, for the 1990 sample, we use the series issued in 1986 and 1989 and for the 1991 sample we use the series issued in 1987 and 1990. This gives a total of 40 time series of profits.

As Chen and Johnson (1985) point out, given that we create an option portfolio using options which are mispriced relative to the Black and Scholes model, using the Black–Scholes hedge ratio does not create a riskless position and because of this the results of the test may be biased. Chen and Johnson (1985) show how a modified hedge ratio can be calculated which takes into account the fact that the option is mispriced. To correct for the inconsistency of using the Black–Scholes hedge ratio, we also investigate the above mentioned strategies using the modified deltas as in Chen and Johnson.

### *Delta-gamma and delta-vega hedges*

A portfolio which is delta-neutral will not be entirely risk-free if there is also uncertainty with respect to other factors, such as the underlying asset's volatility, the option's delta, or the interest rate. Therefore the portfolio should also be made neutral in vega, in gamma and in rho which measure respectively the option's sensitivity with respect to the asset's volatility, the option's delta and the interest rate.

If we study the efficiency of an option market with a delta-neutral trading strategy, we may come to a false conclusion if the delta-neutral portfolios are not risk-free. First, we may conclude that the market is inefficient because a delta-neutral trading strategy leads to positive profits which in reality are normal rewards for the risk of our portfolio. Second, we may conclude that the market is efficient because the delta-neutral trading strategy earns zero returns,

[7] In theory we should also have included interest expenses and incomes when calculating daily profits. However, the interest expenses/incomes are very small on a daily basis, also in relation to the profits on the hedge portfolios. Therefore we will simply ignore the interest effects. Note also that for a given arbitrage portfolio, the total cash position can be positive or negative. Therefore, the total effects of borrowing and lending can be self cancelling over time (see Wei, 1994).

while the truth is that a negative return would be appropriate given the risk of the portfolio.[8]

As argued by Hull (1997, p.331), once a portfolio is neutral in delta, then vega and gamma can be considered to be most important. Therefore, besides trading strategies which are neutral in delta only, we will also consider strategies which are neutral in delta and vega, and in delta and gamma.[9]

To illustrate, consider a delta-gamma neutral trading strategy. In general, in order for an option portfolio to be neutral in two factors we need three option positions:

$$P_t = \lambda_{A,t}C_{A,t} + \lambda_{B,t}C_{B,t} + \lambda_{C,t}C_{C,t} \tag{1}$$

where $P_t$ is the value of the portfolio at time $t$ and $\lambda_{i,t}$ is the position taken in option $i$. Normalizing $\lambda_{A,t}$ to 1, it is straightforward to show that in order for the portfolio in (1) to be neutral in delta and gamma, $\lambda_{B,t}$ and $\lambda_{C,t}$ have to be chosen as:

$$\lambda_{B,t} = \frac{\Delta_{A,t}\Gamma_{C,t} - \Delta_{C,t}\Gamma_{A,t}}{\Delta_{C,t}\Gamma_{B,t} - \Delta_{B,t}\Gamma_{C,t}} \qquad \lambda_{C,t} = \frac{\Delta_{B,t}\Gamma_{A,t} - \Delta_{A,t}\Gamma_{B,t}}{\Delta_{C,t}\Gamma_{B,t} - \Delta_{B,t}\Gamma_{C,t}} \tag{2}$$

The trading strategy investigated here involves finding triplets of options $A$, $B$ and $C$, for which option $A$ is priced too high relative to option $B$ and for which option $B$ is priced too high relative to option $C$, while at the same time $\lambda_{C,t} > \lambda_{B,t} > \lambda_{A,t}$. Thus we look for triplets of options such that:

$$\frac{C^{\text{mkt}}_{A,t}}{C^{\text{mkt}}_{B,t}} > \frac{C^{\text{mod}}_{A,t}}{C^{\text{mod}}_{B,t}}, \quad \frac{C^{\text{mkt}}_{B,t}}{C^{\text{mkt}}_{C,t}} > \frac{C^{\text{mod}}_{B,t}}{C^{\text{mod}}_{C,t}} \quad \text{and} \quad \lambda_{A,t} < \lambda_{B,t} < \lambda_{C,t} \tag{3}$$

We start by assigning the longest-to-maturity option as option $A$, the second longest-to-maturity option as option $B$ and the shortest-to-maturity option as option $C$. If the ordering obtained with these options does not fulfil the requirement in (3) then the second longest-to-maturity option is assigned as option $A$, the longest-to-maturity option is assigned as option $B$ and the shortest-to-maturity option is assigned as option $C$. This strategy ensures that we always have the largest position in the option that is relatively cheapest, while we have the smallest position in the most expensive option.

As with the delta-neutral trading strategy, both an *ex post* and an *ex ante* strategy are investigated. Also, the strategies are analysed with zero transaction costs and with one-way transaction costs of *f* 1.00 per contract, implying that we have four different delta-gamma neutral trading strategies.

Trading strategies which are neutral in delta and vega are investigated in a completely analogous way as the trading strategies which are neutral in delta and gamma which we just described. The only difference is of course that in (2)

[8] This latter situation may occur for instance if the short positions in the call options result in a portfolio with a negative beta.

[9] Vega neutrality is more important for long-term call options, while gamma neutrality is more important for short-term call options.

$\Gamma_{i,t}$ should be replaced by $\Lambda_{i,t}$. Here also, we investigate *ex post* as well as *ex ante* strategies and we take the case where transaction costs are zero and where there are one-way transaction costs of *f* 1.00 per contract.

Applying the same reasoning as in the case of the delta-neutral trading strategies, the strategies described here will not be risk-free if the Black–Scholes hedge ratios are used, given that the options are mispriced relative to the Black and Scholes model. Therefore, we also investigate the delta-gamma and delta-vega neutral trading strategies using the modified hedge ratios as suggested by Chen and Johnson (1985). Since the modified Chen–Johnson hedge ratios sometimes lead to large option positions, thereby causing outliers, we restrict both $\lambda_{A,t}$ and $\lambda_{B,t}$ to be no larger than 10. In other words, we assume that traders will not use more than 10 option contracts to hedge a position in one other option contract.

## 3. RESULTS

In order to analyse the efficiency of the market for DLTCs, the median and average profits are calculated for each strategy, as well as the concomitant standard deviations. The autocorrelations of the daily profits, which are not reported here,[10] are always quite small and do not impose any problem for the calculated standard errors.

### *Delta-neutral trading strategies*

In Table 2 we present the results for the delta-neutral trading strategies when the Black–Scholes hedge ratios are used. Table 3 presents the same results in case the modified hedge ratios as in Chen and Johnson (1985) are used.

The first two columns in Table 2 present the guilder profits for an *ex post* delta-neutral trading strategy with zero transaction costs. This situation can be considered to be a benchmark, representing the profits which a trader could have made if he did not have to pay any transaction costs and if he could trade immediately at the observed market prices. Such a trader could have made average profits which are significantly larger than zero in five out of the ten series which are investigated. Also, only in two out of the ten series is the average profit (not significantly) smaller than zero. Moreover, these losses are small relative to the profits in the other series.

The subsequent columns in Table 2 show that once a trader has to pay one-way transaction costs of *f* 1.00 per contract, he would have made an average profit which is significantly larger than zero in only two out of the ten series. However, only three of the series have average profits (not significantly) smaller than zero.

From the last four columns in Table 2 we can conclude that the supposed arbitrage opportunities disappear within one day. When an *ex ante* strategy is used there is no average trading profit significantly larger than zero either with or without transaction costs. When transaction costs are zero, only in three series would a trader have made positive average profits, while with one-way

[10] These autocorrelations, as well as other additional summary statistics on the results from our hedging strategies, are available on request from the authors.

**Table 2.** Results of a delta neutral trading strategy with long and short maturity call options[a]

| | *Ex post* | | | | *Ex ante* | | | |
|---|---|---|---|---|---|---|---|---|
| | *c* = *f* 0.00[b] | | *c* = *f* 1.00 | | *c* = *f* 0.00 | | *c* = *f* 1.00 | |
| | 1990[c] | 1991 | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| | | | | Akzo | | | | |
| Median | 3.32 | 8.90 | –0.29 | 6.73 | 0.00 | –1.45 | –4.45 | –3.62 |
| Average | 6.11 | 362.1 | 0.74 | 347.1 | 2.51 | 576.9 | –2.91 | 561.0 |
| std.dev. | 57.9 | 1321 | 56.9 | 1313 | 54.6 | 1495 | 54.8 | 1487 |
| *N* | 106 | 15 | 106 | 15 | 94 | 6 | 94 | 6 |
| | | | | KLM | | | | |
| Median | 9.49 | 1.81 | 4.87 | –0.54 | –3.94 | –4.43 | –7.95 | –6.88 |
| Average | 7.05** | –2.56 | 2.88 | –7.47 | –2.58 | –2.37 | –6.79 | –4.76 |
| std.dev. | 18.0 | 24.9 | 18.1 | 28.3 | 19.2 | 14.9 | 19.2 | 14.9 |
| *N* | 85 | 12 | 85 | 12 | 70 | 5 | 70 | 5 |
| | | | | Philips | | | | |
| Median | 0.00 | 6.30 | –2.45 | 0.31 | 0.00 | 0.00 | –5.88 | –3.66 |
| Average | 2.84 | 11.64** | –3.51 | 0.40 | –1.73 | –7.92 | –8.17 | –18.44 |
| std.dev. | 28.6 | 41.8 | 28.8 | 41.5 | 29.4 | 40.1 | 29.6 | 42.7 |
| *N* | 106 | 84 | 106 | 84 | 95 | 67 | 95 | 67 |
| | | | | Royal Dutch | | | | |
| Median | 14.87 | 27.98 | 9.89 | 23.68 | –2.52 | –0.32 | –7.34 | –4.01 |
| Average | 13.09* | 27.26** | 8.35 | 23.17** | 4.31 | –0.11 | –0.42 | –14.99 |
| std.dev. | 74.5 | 72.8 | 74.5 | 72.9 | 78.1 | 76.0 | 78.1 | 76.0 |
| *N* | 107 | 83 | 107 | 83 | 97 | 64 | 97 | 64 |
| | | | | Unilever | | | | |
| Median | –7.59 | 29.08 | –12.07 | 24.50 | –11.47 | 10.00 | –16.17 | 5.20 |
| Average | –2.75 | 29.33** | –7.27 | 24.88* | –8.32 | –4.82 | –12.85 | –9.31 |
| std.dev. | 140.0 | 85.7 | 140.1 | 85.8 | 137.5 | 95.2 | 137.5 | 95.2 |
| *N* | 105 | 40 | 105 | 40 | 94 | 25 | 94 | 25 |

[a] The numbers in the table indicate the median, average and standard deviation of the trading profits in guilders, as well as the number of arbitrage possibilities, *N*, out of a maximum number of observations of 130. Trading profits are expressed in guilders $\times$100.

[b] *c* indicates the one-way, per contract (=100 options) transaction costs.

[c] The years 1990 and 1991 indicate the year of observation. In 1990 trading strategies are based on the 1986 and the 1989 call options series; in 1991 trading strategies are based on the 1987 and 1990 call options series.

* indicates that the average trading profit is significantly larger than zero at the 5% level; ** indicates that the average trading profit is significantly larger than zero at the 1% level.

transaction costs of *f* 1.00 per contract all but one of the average profits are negative.

**Table 3.** Results of a delta neutral trading strategy with long and short maturity call options, using hedge ratios as in Chen and Johnson[a]

| | *Ex post* | | | | *Ex ante* | | | |
|---|---|---|---|---|---|---|---|---|
| | $c = f\,0.00$[b] | | $c = f\,1.00$ | | $c = f\,0.00$ | | $c = f\,1.00$ | |
| | 1990[c] | 1991 | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| | | | | Akzo | | | | |
| Median | 3.05 | 9.87 | 0.06 | 7.67 | 0.00 | –19.87 | –4.39 | –22.06 |
| Average | 5.36 | 93.16 | 0.23 | 79.90 | 2.13 | 695.41 | –3.05 | 678.96 |
| std.dev. | 56.1 | 281.7 | 56.2 | 281.1 | 54.3 | 1665 | 54.4 | 1658 |
| *N* | 106 | 13 | 106 | 13 | 94 | 5 | 94 | 5 |
| | | | | KLM | | | | |
| Median | 9.67 | 3.87 | 4.89 | 1.61 | –3.53 | –4.26 | –7.81 | –6.59 |
| Average | 6.68** | –2.14 | 2.62 | –7.08 | –2.79 | –1.50 | –6.89 | –3.85 |
| std.dev. | 17.6 | 23.7 | 17.7 | 26.7 | 18.7 | 16.5 | 18.7 | 16.5 |
| *N* | 85 | 11 | 85 | 11 | 70 | 4 | 70 | 4 |
| | | | | Philips | | | | |
| Median | 0.00 | 6.36 | –2.43 | 1.89 | 0.00 | 0.00 | –5.63 | –3.87 |
| Average | 2.05 | 10.73** | –3.82 | 0.18 | –1.91 | –7.40 | –7.85 | –17.24 |
| std.dev. | 26.7 | 40.2 | 27.0 | 40.1 | 28.6 | 38.0 | 28.8 | 40.2 |
| *N* | 106 | 83 | 106 | 83 | 95 | 66 | 95 | 66 |
| | | | | Royal Dutch | | | | |
| Median | 15.84 | 27.97 | 10.91 | 23.57 | –2.72 | –0.50 | –7.84 | –4.39 |
| Average | 13.39* | 27.18** | 8.65 | 23.10** | 0.86 | –10.86 | –3.87 | –14.93 |
| std.dev. | 74.3 | 72.5 | 74.3 | 72.6 | 71.2 | 75.8 | 71.2 | 75.8 |
| *N* | 102 | 83 | 102 | 83 | 92 | 64 | 92 | 64 |
| | | | | Unilever | | | | |
| Median | –8.53 | 28.92 | –13.02 | 24.53 | –12.27 | 10.00 | –16.76 | 5.22 |
| Average | –2.73 | 29.18** | –7.22 | 24.76* | –7.71 | –4.88 | –12.21 | –9.34 |
| std.dev. | 139.4 | 85.1 | 139.4 | 85.1 | 136.8 | 94.4 | 136.8 | 94.4 |
| *N* | 100 | 40 | 100 | 40 | 89 | 25 | 89 | 25 |

[a] The numbers in the table indicate the median, average and standard deviation of the trading profits in guilders, as well as the number of arbitrage possibilities, *N*, out of a maximum number of observations of 130. Trading profits are expressed in guilders $\times 100$.
[b] *c* indicates the one-way, per contract (= 100 options) transaction costs.
[c] The years 1990 and 1991 indicate the year of observation. In 1990 trading strategies are based on the 1986 and the 1989 call options series; in 1991 trading strategies are based on the 1987 and 1990 call options series.
* indicates that the average trading profit is significantly larger than zero at the 5% level; ** indicates that the average trading profit is significantly larger than zero at the 1% level.

These results do not change much when the Chen–Johnson hedge ratios are used. The results in Table 3 only show small differences from the results in Table

2, except for the *ex post* results of the Akzo options in 1991, which is caused by one big profit which disappears with the Chen–Johnson ratios. There is no systematic difference between the results based on the Black–Scholes hedge ratios and the results based on the Chen–Johnson hedge ratios.

If the profits made with a delta-neutral trading strategy are risk-free then Tables 2 and 3 suggest that the Dutch market for long-term call options is efficient. Although half of the series show an average profit which is significantly larger than zero, most of these profits disappear once transaction costs are introduced. Moreover, there are no significant profits in an *ex ante* strategy, in which a trader has to wait one day before he can trade on the basis of observed mispricings.

### *Delta-vega neutral trading strategies*

The results of a trading strategy that is neutral in both delta and vega, i.e. which controls both for the uncertainty in the price of the underlying and its volatility, are presented in Table 4 for the Black–Scholes hedge ratios and in Table 5 for the Chen–Johnson hedge ratios.

For the *ex post* strategies the results in Table 4 are clearly very similar to the results of the delta-neutral trading strategies in Table 2. In Table 4 we find that without transaction costs four out of the nine series show an average profit significantly larger than zero. After the introduction of one-way transaction costs of *f* 1.00 per contract only one of these remains, while four of the nine series show losses.

With the *ex ante* strategies all these significant profit opportunities disappear as was the case with the delta-neutral trading strategies. However, with the delta-vega neutral trading strategies the average profits are more often positive than with the trading strategies which are only neutral in delta. When there are no transaction costs, the *ex ante* average profits in Table 4 are positive in six out of nine series and with transactions they are positive in five out of nine series. However, given that the variation within the observed series is of the same order of magnitude as the variation between the series and that the variation of the profits appears to be somewhat larger for the delta-vega neutral trading strategies relative to the delta-neutral trading strategies, we cannot conclude that the delta-vega hedges are superior to the delta-hedges.

In slight contrast to the results in Tables 2 and 3, the results in Tables 4 and 5 indicate that now it does matter whether we use Chen–Johnson hedge ratios or Black–Scholes hedge ratios. The pattern of the results is the same for Table 5 as for Table 4, in that an *ex post* strategy shows a nontrivial number of significant profits, which disappear in the *ex ante* strategy and/or when transaction costs are taken into account. For individual series the differences between using the Black–Scholes hedge ratios and the Chen–Johnson hedge ratios are now somewhat more apparent than for the delta-neutral trading strategies in Tables 2 and 3, although Tables 4 and 5 appear to be roughly in line with each other. Once again, there does not seem to be any pattern from the use of these different hedge ratios.

Overall, the conclusion that we can derive for the delta-vega neutral trading strategy is the same as the conclusion from the delta-neutral trading strategy.

**Table 4.** Results of a delta and vega neutral trading strategy with long, medium and short maturity call options[a]

| | *Ex post* | | | | *Ex ante* | | | |
|---|---|---|---|---|---|---|---|---|
| | $c = f\,0.00$[b] | | $c = f\,1.00$ | | $c = f\,0.00$ | | $c = f\,1.00$ | |
| | 1990[c] | 1991 | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| | | | | Akzo | | | | |
| Median | –1.03 | –17.01 | –10.35 | –19.88 | 3.74 | 15.93 | –3.60 | 13.14 |
| Average | 4.72 | –4.11 | –3.68 | –10.34 | 107.83 | 37.06 | 95.91 | 19.30 |
| std.dev. | 76.0 | 28.6 | 78.1 | 26.8 | 781.2 | 66.7 | 779.6 | 79.9 |
| *N* | 32 | 6 | 32 | 6 | 32 | 3 | 32 | 3 |
| | | | | KLM | | | | |
| Median | 14.78 | – | 9.55 | – | –2.94 | – | –22.44 | – |
| Average | 14.47** | – | 7.67 | – | 14.01 | – | –1.08 | – |
| std.dev. | 22.3 | – | 22.0 | – | 86.2 | – | 87.9 | – |
| *N* | 22 | – | 22 | – | 19 | – | 19 | – |
| | | | | Philips | | | | |
| Median | 6.61 | 6.55 | 1.47 | 2.77 | –3.80 | –0.98 | –10.54 | –41.08 |
| Average | –8.17 | 7.83** | –33.60 | 1.87 | –3.57 | –0.51 | –31.67 | –38.10 |
| std.dev. | 118.4 | 13.2 | 246.4 | 13.5 | 20.6 | 20.2 | 138.0 | 39.2 |
| *N* | 45 | 34 | 45 | 34 | 41 | 31 | 41 | 31 |
| | | | | Royal Dutch | | | | |
| Median | 27.69 | 55.56 | 20.48 | 51.50 | –18.35 | –9.77 | –26.59 | –26.51 |
| Average | 28.30 | 258.20** | 21.79 | 229.62** | –99.10 | 50.49 | –106.78 | 37.83 |
| std.dev. | 103.0 | 492.9 | 103.2 | 479.0 | 439.3 | 1789 | 439.6 | 1793 |
| *N* | 32 | 29 | 32 | 29 | 30 | 34 | 30 | 34 |
| | | | | Unilever | | | | |
| Median | –18.54 | 42.12 | –24.76 | 36.58 | 27.52 | 35.57 | 19.89 | 26.24 |
| Average | –15.72 | 36.43* | –22.15 | 30.73 | 74.88 | 36.72 | 68.20 | 29.59 |
| std.dev. | 123.7 | 84.2 | 123.5 | 84.2 | 277.3 | 198.2 | 278.5 | 198.4 |
| *N* | 9 | 18 | 9 | 18 | 8 | 18 | 8 | 18 |

[a] The numbers in the table indicate the median, average and standard deviation of the trading profits in guilders, as well as the number of arbitrage possibilities, *N*, out of a maximum number of observations of 130. Trading profits are expressed in guilders $\times 100$.

[b] *c* indicates the one-way, per contract (= 100 options) transaction costs.

[c] The years 1990 and 1991 indicate the year of observation. In 1990 trading strategies are based on the 1986 and the 1989 call options series; in 1991 trading strategies are based on the 1987 and 1990 call options series.

* indicates that the average trading profit is significantly larger than zero at the 5% level; ** indicates that the average trading profit is significantly larger than zero at the 1% level.

The Dutch market for long-term call options does not show any serious inefficiencies. Any arbitrage profits in an *ex post* strategy quickly disappear once

**Table 5.** Results of a delta and vega neutral trading strategy with long, medium and short maturity call options, using hedge ratios as in Chen and Johnson[a]

| | *Ex post* | | | | *Ex ante* | | | |
|---|---|---|---|---|---|---|---|---|
| | *c* = *f* 0.00[b] | | *c* = *f* 1.00 | | *c* = *f* 0.00 | | *c* = *f* 1.00 | |
| | 1990[c] | 1991 | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| | | | | Akzo | | | | |
| Median | 9.75 | –3.56 | 6.54 | –12.27 | 0.00 | –16.48 | –11.14 | –28.40 |
| Average | 44.66** | 8.95 | 35.76** | –0.12 | 125.29 | –2.78 | 28.75 | –19.32 |
| std.dev. | 103.8 | 37.6 | 100.6 | 37.7 | 565.4 | 31.9 | 802.5 | 39.9 |
| *N* | 33 | 3 | 33 | 3 | 37 | 3 | 37 | 3 |
| | | | | KLM | | | | |
| Median | 10.91 | – | 2.23 | – | –3.24 | – | –23.17 | – |
| Average | 13.22** | – | 7.15 | – | –78.84 | – | –92.08 | – |
| std.dev. | 21.2 | – | 21.6 | – | 327.0 | – | 325.1 | – |
| *N* | 19 | – | 19 | – | 19 | – | 19 | – |
| | | | | Philips | | | | |
| Median | 6.69 | –2.07 | 1.44 | –9.47 | –2.29 | 0.00 | –9.21 | –40.20 |
| Average | 3.66 | 0.81 | –2.05 | –7.19 | –1674.1 | 20.66 | –1684.8 | –17.35 |
| std.dev. | 31.4 | 13.4 | 31.3 | 13.4 | 10807 | 85.6 | 10806 | 100.4 |
| *N* | 19 | 9 | 19 | 9 | 41 | 31 | 41 | 31 |
| | | | | Royal Dutch | | | | |
| Median | 31.37 | 176.80 | 25.22 | 166.09 | –12.65 | 28.03 | –21.26 | 23.87 |
| Average | 50.91* | 245.38** | 29.70 | 225.35** | –101.12 | 4923.9 | –108.71 | 4891.1 |
| std.dev. | 117.8 | 3095 | 117.9 | 307.7 | 450.8 | 19982 | 451.2 | 19895 |
| *N* | 30 | 14 | 30 | 14 | 30 | 34 | 30 | 34 |
| | | | | Unilever | | | | |
| Median | –31.01 | 48.23 | –35.01 | 41.94 | –25.43 | 34.55 | –31.66 | 25.24 |
| Average | –25.57 | 62.84** | –31.46 | 57.13* | –19.04 | 33.46 | 25.26 | 26.75 |
| std.dev. | 130.8 | 135.2 | 131.0 | 134.8 | 258.1 | 186.9 | 258.9 | 187.4 |
| *N* | 7 | 18 | 7 | 18 | 9 | 18 | 9 | 18 |

[a] The numbers in the table indicate the median, average and standard deviation of the trading profits in guilders, as well as the number of arbitrage possibilities, *N*, out of a maximum number of observations of 130. Trading profits are expressed in guilders $\times$100.
[b] *c* indicates the one-way, per contract (= 100 options) transaction costs.
[c] The years 1990 and 1991 indicate the year of observation. In 1990 trading strategies are based on the 1986 and the 1989 call options series; in 1991 trading strategies are based on the 1987 and 1990 call options series.
* indicates that the average trading profit is significantly larger than zero at the 5% level; ** indicates that the average trading profit is significantly larger than zero at the 1% level.

transaction costs are taken into account and once we use an *ex ante* strategy. Compared to the delta-neutral trading strategy there are now somewhat larger differences between using the Black–Scholes hedge ratios and using the Chen–Johnson hedge ratios. Also, the profits of the *ex ante* strategy seem to be positive more often in the delta-vega neutral strategies than in the delta-neutral strategies, but the profits in the delta-vega neutral strategies also seem to be more variable. This may indicate that controlling for both the uncertainty in the price of the underlying and its volatility does not add much beyond controlling for only price uncertainty in this kind of trading strategies.

*Delta-gamma neutral trading strategies*

A trading strategy that is neutral in both delta and gamma takes into account that the option portfolio is not only sensitive to changes in the price of the underlying but also to changes in the deltas. In other words, a delta-gamma neutral strategy takes into account nonlinearities in the hedge portfolio return as a function of the price of the underlying.[11] The results of such a strategy are presented in Table 6 for the Black–Scholes hedge ratios and in Table 7 for the Chen–Johnson hedge ratios.

In Table 6 we can observe that for the *ex post* strategy with no transaction costs six out of nine average profits are significantly larger than zero, while there is only one loss. After introducing transaction costs, three out of nine average profits are significantly larger than zero and only two average losses occur.

When there are no transaction costs even the *ex ante* strategy in Table 6 still shows one average profit which is significantly larger than zero. Once a one-way transaction cost of *f* 1.00 per contract is taken into account this profit disappears. As with the delta-vega neutral strategy the number of losses in the delta-gamma neutral strategy is smaller than in the delta-neutral strategy of Table 2. However, here also the variability of the profits seems to be rather large both within and between the observed series.

Also as in the delta-vega neutral trading strategies, the differences between using the Black–Scholes hedge ratios and the Chen–Johnson hedge ratios are larger than for the delta-neutral trading strategies, but the results in Tables 6 and 7 still seem to be roughly in line with each other. Note however, that the number of significant profits in Table 7 is much smaller than in Table 6.

The general conclusion that can be derived from Tables 6 and 7 is once again that the option market studied in this paper does not show any serious inefficiences. Analogous to the delta-neutral and delta-vega neutral trading strategy, any perceived *ex post* arbitrage possibility disappears when a more appropriate *ex ante* strategy is used and when transaction costs are taken into account. Also, as in the case of controlling for volatility risk, making a trading strategy neutral in both delta and gamma does not add much to the trading strategies which are neutral in delta only.

## 4. SUMMARY AND CONCLUSIONS

In this study we have investigated the efficiency of the market for Dutch long-term call options (DLTCs). We have studied delta, delta-vega and delta-gamma

[11] This is because the gamma takes the second derivative of the option price with respect to the underlying value into account as well.

**Table 6.** Results of a delta and gamma neutral trading strategy with long, medium and short maturity call options[a]

| | *Ex post* | | | | *Ex ante* | | | |
|---|---|---|---|---|---|---|---|---|
| | *c* = *f* 0.00[b] | | *c* = *f* 1.00 | | *c* = *f* 0.00 | | *c* = *f* 1.00 | |
| | 1990[c] | 1991 | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| | | | | | Akzo | | | |
| Median | 17.82 | –28.53 | 8.93 | –33.28 | 2.48 | –17.49 | –5.23 | –22.15 |
| Average | 26.75** | –15.82 | 20.39* | –20.66 | 30.64 | –253.66 | 23.80 | –261.15 |
| std.dev. | 56.0 | 42.4 | 56.2 | 42.2 | 91.6 | 426.9 | 91.6 | 423.9 |
| *N* | 22 | 6 | 22 | 6 | 19 | 3 | 19 | 3 |
| | | | | | KLM | | | |
| Median | 9.47 | – | 6.00 | – | 3.00 | – | –3.70 | – |
| Average | 18.13* | – | 8.28 | – | 70.78* | – | 63.96 | – |
| std.dev. | 47.7 | – | 45.45 | – | 214.0 | – | 213.3 | – |
| *N* | 20 | – | 20 | – | 28 | – | 28 | – |
| | | | | | Philips | | | |
| Median | 2.51 | 6.16 | –1.99 | 1.21 | –3.39 | 0.00 | –7.55 | –8.03 |
| Average | 9.63* | 7.06** | 4.17 | 2.37 | –2.23 | 28.60 | –7.54 | 18.85 |
| std.dev. | 28.0 | 12.2 | 28.1 | 12.4 | 31.5 | 111.3 | 32.4 | 112.7 |
| *N* | 29 | 34 | 29 | 34 | 26 | 31 | 26 | 31 |
| | | | | | Royal Dutch | | | |
| Median | 15.85 | 62.59 | 8.36 | 51.77 | –18.47 | –28.38 | –26.75 | –35.84 |
| Average | 50.79** | 59.21** | 44.16* | 53.23** | 34.74 | –95.49* | 27.26 | –111.25 |
| std.dev. | 130.7 | 72.0 | 130.4 | 71.7 | 347.2 | 216.5 | 347.9 | 220.0 |
| *N* | 28 | 19 | 28 | 19 | 28 | 15 | 28 | 15 |
| | | | | | Unilever | | | |
| Median | –18.91 | 44.86 | –24.94 | 40.65 | 9.08 | 301.12 | 3.59 | 296.46 |
| Average | 5.21 | 269.86 | –0.95 | 257.75 | 57.39 | 6848.1 | 51.42 | 6824.6 |
| std.dev. | 105.9 | 541.9 | 105.2 | 528.7 | 248.8 | 16592 | 249.2 | 16545 |
| *N* | 9 | 3 | 9 | 3 | 8 | 6 | 8 | 6 |

[a] The numbers in the table indicate the median, average and standard deviation of the trading profits in guilders, as well as the number of arbitrage possibilities, *N*, out of a maximum number of observations of 130. Trading profits are expressed in guilders $\times$100.

[b] *c* indicates the one-way, per contract (= 100 options) transaction costs.

[c] The years 1990 and 1991 indicate the year of observation. In 1990 trading strategies are based on the 1986 and the 1989 call options series; in 1991 trading strategies are based on the 1987 and 1990 call options series.

* indicates that the average trading profit is significantly larger than zero at the 5% level; ** indicates that the average trading profit is significantly larger than zero at the 1% level.

neutral trading strategies. With regard to the delta neutral trading strategy we find arbitrage profits for *ex post* strategies without transaction costs. However,

**Table 7.** Results of a delta and gamma neutral trading strategy with long, medium and short maturity call options, using hedge ratios as in Chen and Johnson[a]

| | *Ex post* | | | | *Ex ante* | | | |
|---|---|---|---|---|---|---|---|---|
| | $c = f$ 0.00[b] | | $c = f$ 1.00 | | $c = f$ 0.00 | | $c = f$ 1.00 | |
| | 1990[c] | 1991 | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| | | | | Akzo | | | | |
| Median | 16.90 | –29.09 | 8.61 | –33.73 | 3.87 | – | –3.09 | – |
| Average | 25.75** | –8.28 | 19.05 | –13.07 | 28.16 | – | 21.40 | – |
| std.dev. | 58.7 | 42.7 | 58.8 | 42.4 | 95.9 | – | 96.0 | – |
| *N* | 22 | 5 | 22 | 5 | 18 | – | 18 | – |
| | | | | KLM | | | | |
| Median | 8.74 | – | 5.28 | – | –12.01 | – | –15.46 | – |
| Average | 12.09 | – | 4.56 | – | –16.26 | – | –21.59 | – |
| std.dev. | 37.7 | – | 37.2 | – | 46.0 | – | 45.7 | – |
| *N* | 19 | – | 19 | – | 28 | – | 28 | – |
| | | | | Philips | | | | |
| Median | 4.77 | 6.10 | 0.48 | 1.35 | –1.25 | 0.00 | –5.70 | –7.92 |
| Average | 7.01 | 6.79 | 1.33 | 2.21 | –0.02 | 28.99 | –5.47 | 19.42 |
| std.dev. | 25.5 | 11.8 | 25.9 | 12.0 | 30.1 | 110.8 | 30.9 | 112.2 |
| *N* | 27 | 34 | 27 | 34 | 24 | 31 | 24 | 31 |
| | | | | Royal Dutch | | | | |
| Median | 26.90 | 67.94 | 19.57 | 57.93 | –17.60 | –48.60 | –27.23 | –52.98 |
| Average | 58.25** | 831.28 | 52.41 | 822.51 | –66.82 | –346.46 | –82.15 | –359.98 |
| std.dev. | 131.8 | 3953 | 132.1 | 3943 | 347.9 | 823.8 | 348.3 | 822.2 |
| *N* | 32 | 25 | 32 | 25 | 33 | 21 | 33 | 21 |
| | | | | Unilever | | | | |
| Median | –25.34 | – | –29.54 | – | –12.72 | – | –16.84 | – |
| Average | –11.01 | – | –15.81 | – | 15.65 | – | 9.66 | – |
| std.dev. | 117.7 | – | 117.0 | – | 252.9 | – | 252.5 | – |
| *N* | 7 | – | 7 | – | 10 | – | 10 | – |

[a] The numbers in the table indicate the median, average and standard deviation of the trading profits in guilders, as well as the number of arbitrage possibilities, *N*, out of a maximum number of observations of 130. Trading profits are expressed in guilders $\times$100.
[b] *c* indicates the one-way, per contract (= 100 options) transaction costs.
[c] The years 1990 and 1991 indicate the year of observation. In 1990 trading strategies are based on the 1986 and the 1989 call options series; in 1991 trading strategies are based on the 1987 and 1990 call options series.
* indicates that the average trading profit is significantly larger than zero at the 5% level; ** indicates that the average trading profit is significantly larger than zero at the 1% level.

these profits disappear when transaction costs and/or *ex ante* trading strategies are considered. Results for the Chen–Johnson hedges are about the same as those for the Black–Scholes hedges. The results for the delta-vega and delta-gamma neutral trading strategies are in line with the results for the delta neutral trading strategies. It appears that the delta-vega and delta-gamma strategies lead to more positive results. However, the variability of these results is larger. The difference between the Black–Scholes and the Chen–Johnson ratios turns out to be more important for the delta-vega and delta-gamma hedges than for the simple delta hedges, although this difference does not alter any conclusion with respect to the trading profits.

This leads to two conclusions. The first conclusion is that we do not find any serious inefficiencies in the market for Dutch long-term call options. This result is in line with the outcomes of earlier studies on long term option-like contracts. Both Lauterbach and Schultz (1991) and Wei (1994) find abnormal returns in *ex post* studies. However, if *ex ante* studies are considered, and if transaction costs are taken into account, both studies find that the abnormal returns disappear. Thus, it can be concluded that the results of this study are similar to the results of other studies on long-term option-like contracts which partly use the same methodology. This conclusion is remarkable, however, if we take the findings of Veld and Verboven (1995) into account. In their study they found that warrants are largely overvalued in relation to long-term call options. In other words, it seems that long-term call options, written on the same stock, are priced correctly in relation to each other, but not if they are compared to warrants on the same stock. Veld and Verboven (1995) argue that one of the reasons for the long-lasting overvaluation of warrants in relation to long-term call options is that it is difficult for investors to arbitrage between warrants and long-term call options. The reason for this is that taking a short position in warrants involves an extra risk in the sense that investors who have gone short in warrants actually have to deliver these warrants. This may cause an investor to be ‘squeezed’ on the delivery date, because he is not sure whether he can buy these warrants at a ‘fair price’. The underlying study makes it clear that if a real arbitrage strategy is possible, it is much more difficult to find market inefficiencies.

The second result is that the use of delta-vega and delta-gamma neutral trading strategies leads more often to positive results than the simple delta strategies. On the other hand, the delta-vega and delta-gamma neutral trading strategies also lead to more variable results than the delta strategies. More research on the use of trading strategies with multiple neutral factors may shed more light on this problem.

The analysis in this paper can easily be extended to more factors, such as delta-gamma-vega neutral trading strategies. In a spread strategy, as used in this paper, in order for a trading strategy to be neutral in $n$ factors, generally $n + 1$ options are necessary. In the case that the underlying asset is also included in the trading strategy, generally only $n$ options are necessary in order to make the trading strategy neutral in $n$ factors.

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## APPENDIX: LONG TERM CALL OPTIONS OUTSTANDING IN OUR RESEARCH PERIOD

| | Range of exercise prices during the research period | Introduction month[a] | Scheduled expiration date[a] |
|---|---|---|---|
| Akzo 1986 | *f* 150 | October 1986 | 18-10-91 |
| Akzo 1987 | *f* 180 | October 1987 | 16-10-92 |
| Akzo 1988 | *f* 150 | October 1988 | 15-10-93 |
| Akzo 1989 | *f* 135 | October 1989 | 21-10-94 |
| Akzo 1990 | *f* 80 | October 1990 | 17-10-95 |
| KLM 1986 | *f* 40 | January 1987 | 18-10-91 |
| KLM 1987 | *f* 55 | October 1987 | 16-10-92 |
| KLM 1988 | *f* 35 | October 1988 | 15-10-93 |
| KLM 1989 | *f* 50 | October 1989 | 21-10-94 |
| KLM 1990 | *f* 20 | October 1990 | 17-10-95 |
| Philips 1986 | *f* 55 | October 1986 | 18-10-91 |
| Philips 1987 | *f* 55 | October 1987 | 16-10-92 |
| Philips 1988 | *f* 30 | October 1988 | 15-10-93 |
| Philips 1989 | *f* 45 | October 1989 | 21-10-94 |
| Philips 1990 | *f* 20 | October 1990 | 17-10-95 |
| Royal Dutch 1986 | *f* 210–*f* 105 | October 1986 | 18-10-91 |
| Royal Dutch 1987 | *f* 210–*f* 135 | October 1987 | 16-10-92 |
| Royal Dutch 1988 | *f* 115 | October 1988 | 15-10-93 |
| Royal Dutch 1989 | *f* 145 | October 1988 | 21-10-94 |
| Royal Dutch 1990 | *f* 135 | October 1990 | 17-10-95 |
| Unilever 1986 | *f* 500–*f* 100 | October 1986 | 18-10-91 |
| Unilever 1987 | *f* 140 | October 1987 | 16-10-92 |
| Unilever 1988 | *f* 120 | October 1988 | 15-10-93 |
| Unilever 1989 | *f* 150 | October 1989 | 21-10-94 |
| Unilever 1990 | *f* 145 | October 1990 | 17-10-95 |

[a] Source: European Options Exchange.

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