Tests of Options Market Efficiency
A Study of the European Options Exchange

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Tan How Joo

Department of Accounting and Finance

University of Glasgow

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To my family

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Abstract

The objective of this study is to provide evidence on the efficiency of the stock options market of the European Options Exchange. 'Riskless' spreading and hedging strategies using the Black-Scholes call option pricing model with the Merton dividend adjustment, are used to test market efficiency. The results show that, although for the zero transactions costs case above-normal returns are possible, these returns become negative when the bid-ask spread cost is taken into account. These results persist over the two sample periods studied. Two variations of the trading rule that compute model prices by using the same model but with two different estimators of the standard deviation of the underlying stock's return as inputs to the model, also produce similar results. The study concludes that, with respect to the trading rules used and the sample periods studied, there were no inefficiencies on the stock options market of the European Options Exchange.

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CHAPTER ONE

INTRODUCTION

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Introduction

1.1 Introduction

"A call option is the right to buy a given amount of a security at a given price on or before a specific date" (Bookstaber(1987) p. 1). The security involved in the call option is called the 'underlying security'. The price to be paid is called the 'exercise price' or 'striking price' and the specific date is called the 'maturity date' or 'expiration date'. The call is an 'European' call if it can only be exercised at maturity. If it can be exercised at any time on or before the maturity date, it is known as an 'American' call.

Options were traded in the Netherlands as early as the seventeenth century, during the Dutch tulip boom (Ritchken(1987)). In the UK, there was a well organised and sophisticated market for trading in puts and calls as early as the 1690s and in the US, the first mention of options in American history dated back to 1790 (Malkiel and Quandt(1969)).

Today, options are still being traded in the Netherlands and there is an organised exchange for trading standardised options. This exchange is known as the European Options Exchange (hereinafter EOE) and it is located in Amsterdam. This study is concerned with the efficiency of the EOE.

In this chapter, the objective of this study is stated and the motivation for this research is explained. The hypothesis to be tested is then presented and some basic problems related to the test of the hypothesis are discussed. Next, the importance of the study is highlighted and the chapter ends with an outline of the remaining chapters of this study.

1.2 Objective of this study

The objective of this study is to provide evidence on the efficiency of the EOE. Stock options, precious metals (gold and silver) options, foreign currency options, bond options and stock index options are traded on the EOE. Stock options dominate the market in terms of volume traded. In 1989 and 1988 stock options represented seventy five per cent of the total volume traded on the EOE (EOE Annual Reports 1989 and 1988). This study concentrates on stock options.

1.3 Motivation for this research

The EOE is the largest options exchange in Europe in terms of volume traded (measured as total number of contracts traded). Nearly thirteen and a half million contracts were traded in 1989 (EOE Annual Report 1989). However, despite its opening in Amsterdam more than ten years ago on 4 April 1978, there have been very few studies of this market. Previous studies of options market efficiency have been concentrated particularly on the Chicago Board Options Exchange, with a few later studies relating to the London, Toronto, Sydney and Amsterdam markets. This study is motivated by this lack of evidence and fills this gap by providing hitherto unavailable evidence on the efficiency of the EOE.

There are three known studies of the EOE : Kemna(1987), Beckers(1984) and Van der Hilst(1980). Kemna(1987) is concerned with testing the validity of the Black-Scholes model rather than the efficiency of the EOE. Beckers(1984) tested the efficiency of the EOE but concentrated on the gold options market. Van der Hilst(1980) provided evidence on the efficiency of the stock options market of the EOE. However, this does not rule out the need for further research as Keane(1983) emphasised the need for "a regular programme of research to serve the dual purpose of providing a continuing attestation of the market's efficiency and of acting as a monitoring process, so that any short-term imperfections that might occasionally surface can be quickly identified and eliminated" (p.157). In addition, Kemna(1987) also called for further research on the EOE "in the direction of ex ante testing of market efficiency" (p.25).

Van der Hilst found the EOE to be less than perfectly efficient, but this result must be treated cautiously because transactions costs were ignored in his study. This study also examines the efficiency of the EOE but it differs from the Van der Hilst study in three ways. It uses price quotations downloaded from DATASTREAM in order to overcome the non-simultaneity problem (see Section 1.5 for further elaboration of the non-simultaneity problem). The Van der Hilst study used daily closing stock and option transactions prices, with the potential problem of non-simultaneity in the the data. Furthermore, this study uses the actual bid and ask prices so as to incorporate a component of transactions costs, the bid-ask spread. The Van der Hilst study ignored transactions costs. In addition, both spreading and hedging tests are conducted in this study. Van der Hilst conducted hedging tests only.

1.4 Hypothesis

Fama(1970) defined an efficient market as a market in which "prices always 'fully reflect' available information" (p.383). The terms 'fully reflect' and 'available information' had been described as "vague and non-operational" (Beaver(1981) p.146). However, this definition does imply that if a market is efficient, that is, security prices adjust to new information in a rapid and unbiased manner, trading decisions based solely on existing information will not yield returns in excess of a normal expected return. This is sometimes referred to as 'fair game' efficiency. It is a 'fair game' in the sense that in a market where prices fully reflect all available information, investors cannot expect to earn more than the normal expected return by trading solely on existing information. It is this implication of market efficiency that is of interest to investors, rather than the vague concept of whether security prices fully reflect all available information. This implication is also important because it enables the efficient market hypothesis to be tested. Instead of trying to measure the speed and quality (direction and magnitude) of the adjustment of security prices to new information, market efficiency can be tested by determining whether above-normal returns can be made by using various trading rules. If above-normal returns can be made, then the market is inefficient with respect to the information employed by those trading rules; if not, the market is efficient.

Jensen(1978) stated that market efficiency implies that it is impossible to make economic profits by trading with existing information, where economic profits are "risk adjusted returns net of all costs" (p.96). In practice, investors incur costs when transacting. Hence, when determining whether above-normal returns can be earned by investors, transactions costs must be taken into account. However, zero transactions cost is one of the sufficient conditions for market efficiency (Fama(1970)). Fama argued, however, that it is not a neccesary condition because "as long as transactors take into account all available information, even large transactions costs that inhibit the flow of transactions do not in themselves imply that when transactions do take place, prices will not 'fully reflect' available information" (p.387). Lorie and Hamilton(1973), in a discussion of the neccesary and sufficient conditions for market efficiency, stated that "the neccesary conditions for efficiency are far less stringent" (p.80) and that "exorbitant transaction costs might restrict the frequency of transactions but not distort the prices at which they take place" (p.80). Although exorbitant transaction costs may not distort the prices at which transactions take place, they might cause prices not to 'fully reflect' all available information at all times.

West(1975) pointed out that exorbitant transaction costs "reduce the incentive for investors to arbitrage" (p.33) and as a result "prices are distorted in relation to the prices we would observe in a zero transaction costs environment" (p.33). However, it is still possible for a market with exorbitant transactions costs to be efficient in the fair game sense. That is, as long as no investor can consistently generate an above-normal average rate of return after transactions costs, the market can be said to be efficient. Hence, a market with transactions costs, or even exorbitant transactions costs, need not neccesarily be inefficient in the fair game sense. **Therefore, in this study, efficiency is defined as the inability of any trader to consistently generate an above-normal average rate of return after transactions costs.**

This study uses a trading rule designed to exploit any 'mispricing' of options on the EOE. The trading rule uses DATASTREAM's option pricing model, that is, the Black-Scholes model with Merton's dividend adjustment (see Appendix 1). The model is assumed to be correct so that any deviation of the market price from DATASTREAM's model price is taken as a signal to buy or write the option. Two variations of the trading rule compute model prices by using the same model but with two different estimators of the standard deviation of the underlying stock's return as inputs to the model. To take into account one component of transactions costs, the bid-ask spread, in the calculation of the rate of return, it is assumed that options are bought at the ask price and written at the bid price.

Hedging and spreading strategies are used to set up 'riskless' positions. These positions are held until the end of the sample period, or until the mispricing of the option in the hedge is reversed, or in the case of spreads, until the mispricing of at least one leg of the spread is reversed. During the period the hedges and spreads are held, daily rebalancing is employed to maintain riskless positions.

Since the positions are riskless, no trader can consistently earn an average rate of return after transactions costs in excess of the risk-free interest rate if the market is efficient. Therefore, the null hypothesis of efficiency is $H_0 : u = r_f$ and the alternative hypothesis is $H_1 : u > r_f$, where u is the average rate of return after transactions costs and r_f is the estimated risk-free interest rate. If the market is inefficient with respect to the trading rule used, H_0 will be rejected since it will be possible to earn above-normal average rates of return.

Similarly, if the market is efficient with respect to the trading rule, H_0 cannot be rejected.

1.5 Problems in testing options market efficiency

One main difficulty in conducting studies of this kind is that it involves the joint tests of model validity, market efficiency and data accuracy. Data may be inaccurate because stock and option prices may not have been observed simultaneously, with the result that any mispricing may be illusory. This problem will be elaborated later in this section. Even if the data are accurate, there remains the problem of the joint hypothesis of model validity and market efficiency. If no abnormal returns are found, it could be due to either market efficiency or the use of a mis-specified model. This study assumes that the model used is valid in order to test the efficiency of the EOE.

The Black-Scholes model depends on a number of assumptions which had been described as "unrealistic" (Black (1989) p.67). There have been many attempts to develop alternative models with more realistic assumptions. Jarrow and Rudd(1983) and Hull(1989) reviewed a number of these alternative models.

In addition, empirical evidence on the Black-Scholes model showed that Black-Scholes model values differ systematically from market values (see, for example, Black(1975), Macbeth and Merville(1979), Galai(1983b), Rubinstein(1985) and Kemna(1987)).

In spite of these limitations of the Black-Scholes model, Galai(1983b) concluded, after surveying empirical tests of option pricing models, that "no alternative model consistently offers better predictions of market prices than the Black-Scholes model" (p.68). More recently, Black(1989) noted that "making the assumptions more realistic hasn't produced a formula that works better ......" (p.67). In addition, Hull(1989) reviewed a number of alternatives to the Black-Scholes model and empirical evidence on option pricing and stated that "at present, there does not seem to be any compelling arguments for using any of the models introduced earlier in this chapter in preference to Black-Scholes" (p.318). He further concluded that "in the case of stock options, there is no single model that reflects all the biases which are actually observed in practice. The best strategy appears to be to use an extension of the Black-Scholes model which captures the effects of dividends and early exercise opportunities" (p.319).

This study uses the DATASTREAM option pricing model which is the Black-Scholes model with the Merton dividend adjustment. DATASTREAM also uses the Pseudo-American method to account for early exercise opportunities. Hence, the DATASTREAM model is consistent with the conclusion by Hull(1989) that using "an extension of the Black-Scholes model" (p.319) appears to be the best strategy.

As mentioned above, data inaccuracy may be due to the non-simultaneity of stock and option prices. This refers to the problem where the reported option price and the reported stock price are recorded at different times of the day. This can cause inaccuracies in option markets efficiency tests when the stock price is used as an input to the option pricing model and the resulting model price is compared to the reported option price to detect the mispricing of options. Even if the option is not mispriced, it can appear to be mispriced when the reported stock price that is used in the model is not the stock price that prevailed in the market when the option price is reported. This illusory mispricing will lead to an apparently profitable hedging strategy when in fact no such profitable strategy exists. This is because the researcher assumes that a hedge position can be set up using the reported prices. But, since the reported stock price is not equal to the stock price at the time the option price is observed, the hedge position cannot be established with the reported stock and option prices. In the case of spreading strategies, the reported price of one option in the spread may have been observed at a time different from that of the price of the other option in the spread. In practice, it may not be possible to execute a spreading strategy based on the reported prices because of the non-simultaneity of the option prices. This problem is in addition to the problem of apparent mispricing caused by the non-simultaneity of the stock and option prices. Bookstaber(1981) illustrated these problems with an example.

1.6 Importance of study

The main contribution of this study is to provide hitherto unavailable evidence on the efficiency of the EOE. Evidence on the efficiency of the EOE is important because of the potential implications of such evidence for market participants. Market participants' view of the efficiency of the market influences the investment strategy adopted by them. This study examines the fair game notion of efficiency, that is, the ability or inability of any trader to consistently generate an above-normal average rate of return after transactions costs. If the evidence suggests that the market is inefficient, the implication is that above-normal profit opportunities exist for at least some traders. It may then be worthwhile for those traders to look for mispriced options so as to exploit those profit opportunities. Such a strategy is obviously not without costs. So, if the market is not inefficient, a strategy of actively seeking mispriced options is a waste of the traders' resources since, on average, no above-normal profit opportunities exist.

In addition to providing evidence on the efficiency of the EOE, this study also highlights the following :

(i) the impact of the bid-ask spread on trading profit. The profitability of the trading rule is examined with and without the bid-ask spread cost so as to isolate the impact of the spread on profits. Actual bid and ask quotations are used in this study. Phillips and Smith(1980) had shown that transaction cost is an important factor in determining whether above-normal average returns can be earned. Many previous studies have either ignored the bid-ask spread as a transactions cost or used an estimate of the spread. In particular, a previous study of the EOE by Van der Hilst(1980) ignored transactions cost and found the market to be less than perfectly efficient (see Chapter Three Section 3.2).

(ii) the persistence (or otherwise) of efficiency or inefficency over time. Two sample periods are used to test for persistence. Keane(1983) identified persistence as one of the criteria an inefficiency must satisfy for it to be exploitable.

(iii) the difficulties involved in computing a rate of return for options trading when option writing is involved. A method of computing the rate of return is suggested and used in this study.

1.7 Outline of chapters

The rest of the study is organised as follows :

Chapter Two provides an overview of some of the institutional aspects of the EOE in order to provide background information on this market. The EOE's formation, growth, the terms of the stock option contract, margin requirements and minimum commissions are described, together with the taxation of option trading profits in the Netherlands and the trading of options on the EOE.

Chapter Three reviews the evidence relating to the efficiency of the Chicago Board Options Exchange and other options markets including the over-the-counter market in the US, the London Traded Options Market, the Toronto Options Exchange, the Australian Traded Options Market and the EOE.

Chapter Four reviews the methodological issues associated with tests of options market efficiency and describes the methodology used in this study. One major issue discussed is the choice of estimators for the standard deviation of the underlying stock's return. This is followed by descriptions of the types of tests carried out, the trading strategies used, the criteria used for determining mispriced options and the method of calculating the rate of return. The problems related to the incorporation of the bid-ask spread cost into the tests and the possibility of premature exercise of options are also addressed, together with the limitations inherent in the daily rebalancing of spreads and hedges.

Chapter Five describes how the data for this study are obtained from DATASTREAM. The DATASTREAM option pricing model is described, followed by a discussion of the advantages and disadvantages of obtaining data from this source. It also describes the calculation of the model values, hedge ratios, time to maturity and states the reasons for the exclusion of certain options. It elaborates on DATASTREAM's method of imputing the implied standard deviation of the underlying stock's return from each option and shows how this implied standard deviation is combined with a historical measure to estimate the stock's volatility.

Chapter Six presents the results of this study and discusses the implications of these results for market efficiency. Some of the results are presented in the tables in Appendix Two.

Chapter Seven provides a summary of this study. The conclusions and limitations of this study are also discussed. The chapter ends with some suggestions for future research.

In addition to the seven chapters, there are four appendices. Appendix One describes the DATASTREAM option pricing model while Appendix Two contains the results of the tests using two alternative estimators of the standard deviation of the underlying stock's return. Appendix Three contains the results of the *ex post* tests with 80 per cent of the bid-ask spread cost, using the DSISD estimator. Appendix Four reports on the values of the skewness measure of the distribution of the rates of return from all tests using the DSISD estimator and also the results of the SIGN test of the median rates of return from the *ex post* tests with 80 per cent of the bid-ask spread cost, using the DSISD estimator.

References

Beaver, W. H. "**Financial Reporting : An Accounting Revolution**", Prentice Hall, Inc., 1981

Beckers, S. "On the Efficiency of the Gold Options Market", **Journal of Banking and Finance**, 1984 pp459-470

Black, F. "Fact and Fantasy in the Use of Options", **Financial Analysts Journal**, July-August 1975 pp36-72

Black, F. "How To Use The Holes In Black-Scholes", **Journal of Applied Corporate Finance**, Winter 1989 pp67-73

Bookstaber, R. "Observed Option Mispricing and the Nonsimultaneity of Stock and Option Quotations", **Journal of Business**, 1981 pp141-155

Bookstaber, R. "**Option Pricing and Investment Strategies**", **Probus Publishing Co.**, 1987

European Options Exchange "**Annual Report 1988**"

European Options Exchange "**Annual Report 1989**"

Fama, E. F. "Efficient Capital Markets : A Review of Theory and Empirical Work", **Journal of Finance**, May 1970 pp383-423

Galai, D. "A Survey of Empirical Tests of Option Pricing Models", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath & Co., Lexington Books, 1983b

Hull, J. "**Options, Futures, and Other Derivative Securities**", Prentice Hall International, 1989

Jarrow, R. and Rudd, A. "**Option Pricing**", Richard D. Irwin Inc, 1983

Jensen, M. C. "Some Anomalous Evidence regarding Market Efficiency", **Journal of Financial Economics**, 1978 pp95-101

Keane, S. "**Stock Market Efficiency**", Philip Allan Publishers Limited, 1983

Kemna, A. "An Empirical Test of the Option Pricing Model Based on Transactions Data of the European Options Exchange", Paper presented to the **European Finance Association Meeting**, 1987

Lorie, J. H. and Hamilton, M. T. "**The Stock Market : Theories and Evidence**", Richard D. Irwin, Inc., 1973

Macbeth, J. D. and Merville, L. J. "An Empirical Examination of the Black-Scholes Call Option Pricing Model", **Journal of Finance**, 1979 pp1173-1186

Malkiel, B., and Quandt, R. "**Strategies and Rational Decisions in the Securities Options Market**", The MIT Press, 1969

Phillips, S. and Smith, C. "Trading Costs for Listed Options: The Implications for Market Efficiency", **Journal of Financial Economics**, 1980 pp179-201

Ritchken, P. "**Options : Theory, Strategy and Applications**", Scott, Foresman and Company, 1987

Rubinstein, M. "Nonparametric Tests of Alternative Option Pricing Models Using All Reported Trades and Quotes On The 30 Most Active CBOE Option Classes from August 23, 1976 through August 31, 1978", **Journal of Finance**, June 1985 pp455-480

Van der Hilst, J. "Marktefficiency op de EOE te Amsterdam", in **Financiering en Belegging**, stand van zaken anno 1980, Ballendux, F. J. (ed), Erasmus Universiteit, Rotterdam (1980)

West, R. R. "On the Difference Between Internal and External Market Efficiency", **Financial Analysts Journal**, November-December 1975 pp30-34

Chapter Two

The European Options Exchange

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The European Options Exchange

2.1 Introduction

This study examines the efficiency of the stock options market of the EOE. The EOE was officially opened by the Dutch Minister of Finance on 4 April 1978. In spite of its location in Amsterdam, the EOE uses English as its official language.

Since its establishment in 1978, the EOE has experienced enormous growth and is now the largest options exchange in Europe in terms of volume (measured as the total number of contracts traded). In 1989 (1988), 13.4 (8.5) million contracts were traded, compared with 9.1 (8.4) million on the London Traded Options Market (EOE Annual Reports 1989 and 1988).

Over the years the EOE had increased its range of products. Options on stocks, gold, bonds, currency, silver and stock indices are now traded on the EOE. However, stock options still dominate in terms of total volume traded. In 1989 and 1988, stock options represented 75% of total volume (EOE Annual Reports 1989 and 1988). This study concentrates on stock options.

Spreading and hedging trading strategies on stock options are used in this study to test the efficiency of the EOE. In order to understand how stock options are traded on the EOE, the next section explains the terms of the EOE stock options contract. The process of executing option orders on the EOE is then described. Since American options can be exercised at or before maturity, the process of assigning exercise notices to option writers is also described to show how option writers can be selected at random to deliver the underlying security. This study involves uncovered call option writing. Uncovered call option writers have to meet the margin requirements of the EOE. These requirements are presented, together with brokers minimum commissions set by the EOE and the taxation of option trading profits in the Netherlands. Although commissions and taxes are ignored in this study, they are nevertheless presented to give some idea of the magnitude of these costs at the EOE.

2.2 The terms of the stock options contract

The EOE, like other organised options exchanges, has standardised the terms of its options contracts. Standardisation, together with the fact that the clearing organisation stands as the opposite party to every trade, facilitates secondary trading of these contracts.

Standardisation applies to the contract size, the expiration date and the exercise price. The price of the option is the only variable element.

The unit of trading is a contract. For stock options, the EOE has standardised the contract size to one hundred underlying shares.

The last trading day and the expiration day are also standardised. The last trading day for an option series is the last day on which trading in the series is possible, whereas the expiration day is the last day on which it is possible to exercise the right given by the option to buy or sell (EOE Explanatory Memorandum 1988). The last trading day is the third business Friday in the expiration month until 1400 hours (EOE Brochure "Stock Option"). The usual trading day starts from 1030 hours and ends at 1630 hours. The expiration day is on the Saturday following this Friday at 1300 hours (EOE "Contract Specifications"). That is, it is possible to exercise the option until this time. All times refer to Amsterdam time.

The above are the official dates and times set by the EOE. Each broker may set an earlier time up to which his client may give orders to trade in the expiring series or instructions to exercise options in these series.

The expiration cycle for stock options is January/April/July/October and the initial time to maturity has been set to three, six and nine months, with the exception of a few stocks where options with initial time to maturity of three, four and five years are traded.

The exercise price is the price at which the holder of the option is entitled to buy or sell the underlying stock if he exercises. The exercise price is quoted per unit of the underlying stock (EOE Explanatory Memorandum 1988).

It is a general rule that no adjustment will be made to reflect a cash dividend paid by the issuer of the underlying stock, whether shares are offered as an alternative or not (EOE Explanatory Memorandum 1988).

2.3 Stock options trading at the EOE

An investor wishing to buy or sell options traded at the EOE may do so by placing an order with a broker. Various types of orders can be placed. This study is concerned with buying, selling and writing options at closing price quotations. Therefore, the appropriate type of order to give to the broker is the market-on-close order, which is defined in Paragraph 12(b) of the Trading Rules as "an order to buy or sell, to be executed as late in the day as possible". Other types of orders are listed and defined in Paragraph 12 of the Trading Rules.

When a broker receives an order, he will transmit the order to the trading floor. Upon receipt of the order, the trader at the floor will either execute it himself or pass it to another trader for execution. All orders must be executed by open outcry at the post designated for that particular class of options (Rules 14 and 16(a)). The broker may trade with three types of traders :

1) Market makers are only permitted to trade for their own accounts and are obliged to make a market in the classes assigned to them. That is, they must make a bid and an offer when asked to do so by the Order Book Official or floor brokers. Such bids and offers are valid for at least five contracts (Regulation 7(B)). To maintain a competitive market, the EOE assigns at least four market makers to each stock option class (Regulation 7A).

2) Order Book Officials are employees of the EOE who supervises trade at a post. They keep the public limit order book and display the book's highest bid and lowest offer for each series . They are also responsible for executing the orders in the book.

3) <u>Floor Brokers</u> executes orders on the floor of the EOE on behalf of their clients or for their own account. However, floor brokers cannot act for their own account unless they have elected not to act for the account of their clients (Rule 32).

Once an order has been executed on the floor, the broker must promptly confirm to the client that the order has been executed (Rule 31(1)).

An investor who has bought a stock option can exercise it at or before maturity if he wishes. To do so, he must notify his broker of his intention. The broker will in turn pass the exercise notice to the clearing organisation. When the clearing organisation receives an exercise notice for a call option, it will randomly assign the exercise notice to a clearing member who has an account containing a written option on the written stock. The clearing member selected will in turn randomly select a broker with the relevant short position and assign the exercise notice to him. The broker will select a client with the relevant short position for re-assignment of the exercise notice. By this random process, any investor who has short positions in the relevant series can be assigned the exercise notice no matter when the short position was entered into.

2.4 Margin requirements

The EOE requires a writer of covered call options to deposit the underlying stock in sufficient quantity to enable the obligations arising from his option transaction to be satisfied in full (EOE Explanatory Memorandum 1988).

The EOE also allows call options to be written uncovered, in which case the writer is required to meet the EOE's minimum margin requirement. This margin requirement is reduced by the premium received from writing the options. The premium is retained by the broker until the position is closed. The minimum margin, net of this premium, can be satisfied by depositing cash or securities. In the case of call options, the minimum margin must be worth not less than the current option premium, plus a percentage of the difference between twice the price of the underlying stock and the exercise price. The percentage is set at regular intervals by the EOE in consultation with the clearing organisations (EOE Explanatory Memorandum 1988).

Expressed in formula form, the minimum margin requirement for call options is :

Margin for calls = Option premium + P% (2S - X) where S = price of the underlying stock,

X = exercise price for the call,

P = a value set by the EOE.

Concessions are granted for "spread orders" and "straddle orders" as defined in Trading Rule 12. In the case of spreads on calls, the margin required is the exercise price of the long leg minus the exercise price of the short leg of the spread. This concession is only granted when the long leg does not expire earlier than the short leg. In the case of straddles, the short leg of the straddle with the higher premium is treated as the naked short position (Swanson(1984)).

Note that the spread orders in this study are not spread orders within the meaning of Rule 12. Rule 12 defined a spread order as an order to buy and to sell **the same number of options** in the same class. Spread orders in this study do not necessarily buy and sell the same number of options. The number of options bought and sold depends on the hedge ratios of the two option series in the spread and they will be the same only by chance. Hence, the concessions for spread orders do not usually apply to the orders in this study.

In the case of uncovered call writing, brokers have to require their clients to provide margin before executing the order (Rules 31(a)(b) and 31(m)). The brokers requirements may be higher than the minimum prescribed by the EOE (EOE Explanatory Memorandum 1988).

2.5 Minimum Commissions

Prior to 1 July 1990, every broker had to charge their clients commissions. The EOE prescribed minimum rates of commission that brokers were required to charge their clients. These rates were given in the EOE brochure "Minimum Commissions, 1988". The actual commissions, however, could be higher than those prescribed by the EOE.

In the case of stock options, the minimum commission per contract was as follows :

Opening Transactions	**DFl.**
Premium of DFl. 0.01 to 1.50	15.00
Premium of DFl. 1.51 or more	22.50
Minimum per order	40.00

Closing Transactions

	DFl.
Premium of DFl. 0.01 to 0.10	No Minimum
Premium of DFl. 0.11 to 1.50	7.50
Premium of DFl. 1.51 or more	15.00
Minimum per Order	30.00

The minimum commission applied to the first ten contracts in an order; no minimum commission was prescribed for contracts above the first ten.

All orders of the same type, for the same series, for the same client, executed on the same day, may be added together before commission was calculated. The four types of orders were : open buy, open sell, close buy and close sell.

For combination orders (for example, spreads and straddles), the first ten contracts for options on the same underlying stock, which were presented as one unit, were subject to the minimum commission. No minimum commission was prescribed for contracts above these ten. If the combination contained one or more opening contracts, the applicable minimum per order for opening transactions would apply. If the combination contained only closing contracts, the applicable minimum per order for closing transactions would apply.

From 1 July 1990, the EOE's minimum commissions have been abolished and commissions are negotiable between brokers and their clients.

2.6 Taxation

In the Netherlands, there is a tax on exchange dealings (stamp duty) of 0.12 percent on the premium, with a maximum of DFl. 1200 per transaction. However, this tax will be scrapped from 1 July 1990 (Financial Times 2 February 1990).

For residents, profits on traded options realised by individuals are tax-exempt; corporations are liable to tax at a normal rate. For non-residents, profits are not taxable unless the income is attributable to a Dutch permanent establishment (Communication with EOE's Commercial Affairs Department).

2.7 Summary

This chapter has provided a brief overview of the institutional aspects of the EOE. The EOE's formation, growth, the terms of the stock options contract, the trading of options at the EOE, minimum margin requirements and minimum commissions have been described, together with the taxation of option trading profits in the Netherlands.

References

European Options Exchange "**Trading Rules, April 1981**"

European Options Exchange "**Trading Regulations**"

European Options Exchange "**Annual Report 1988**"

European Options Exchange "**Annual Report 1989**"

European Options Exchange "**Explanatory Memorandum, 1988**"

European Options Exchange "**Contracts Specifications**"

European Options Exchange "**Stock Options, October 1987**"

European Options Exchange "**Minimum Commissions, 1988**"

Financial Times 2 February 1990

Swanson, J. E. "**The European Options Markets : A New Approach To Investment**", Kluwer Law and Taxation Publishers, 1984

CHAPTER THREE

PREVIOUS STUDIES

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Previous Studies

3.1 Introduction

This study examines the efficiency of the EOE. There has been a number of studies of the efficiency of options markets. Most of these studies were concentrated on the Chicago Board Options Exchange (CBOE), with a few relating to the over-the-counter options markets in the United States, the London Traded Options Markets, the Toronto Options Exchange, the Australian Traded Options Market and the EOE. This chapter reviews the evidence relating to the efficiency of these options markets.

The results of hedging tests are presented in the next section, followed by the results of spreading tests, lower boundary condition tests, convexity condition tests, put-call parity tests and volatilty tests. This chapter ends with a summary.

3.2 Results of hedging tests

Galai(1977) conducted one of the first tests of the efficiency of the CBOE. He used daily data on options traded on the CBOE from 26 April 1973 to 30 November 1973, a total of 152 trading days. Galai used the Black-Scholes model to identify mispriced options. A hedge was set up consisting of an under-priced or over-priced option and the underlying stock and it was liquidated one day later.

The _ex post_ hedging test produced average returns that were significantly different from zero at the five per cent level of significance. This result indicated strongly that his hedge strategy with the Black-Scholes model could locate mispriced options. The conclusion remained unchanged when the estimated risk-free interest rate and the standard deviation of the underlying stock's return were changed. However, when an ad hoc one per cent transactions costs was imposed on buying or selling of the stock and option, almost all the hedge returns were eliminated.

In the case of the _ex ante_ hedging test, the average returns were lower than those from the _ex post_ tests. The one day delay in the execution of the hedges had reduced the profitability of Galai's trading rule. However, the average returns, ignoring transactions costs, were still significantly different from zero. Hence, Galai concluded that his _ex ante_ tests suggested that "the CBOE might not have been perfectly efficient during the period investigated and abnormal profit opportunities did exist" (p.189). However, Phillips and Smith(1980) showed that these significant returns may be completely eliminated if the bid-ask spread was considered.

Blomeyer and Klemkosky(1983) also tested the efficiency of the CBOE using a hedging strategy. Both the Roll(1977) model and the Black-Scholes model, together with the Chiras and Manaster(1978) weighted implied standard deviation, were used. The data consisted of twelve trading days transactions data from the period July 1977 to June 1978. These twelve days were selected one day per month from the week following the third Friday of each month.

In the ex post test, the hedge position was set up immediately upon observing the mispriced option and was maintained till the next option transaction. The ex post test produced mean returns that were significantly greater than zero at the five per cent level for fifteen out of eighteen stocks for both the Black-Scholes and the Roll models. Both models performed well in most cases in identifying mispriced options.

In the ex ante test, two lags were tested. The hedges were set up with the next available transaction prices occurring at least (i) five minutes and (ii) fifteen minutes after identification of the mispriced option and were held for one month. All the ex ante grand mean (average over all periods and all stocks) returns were significantly greater than zero at the five per cent level. However, all the mean returns turned negative when the risk-free rate of interest and transactions costs were taken into account. Blomeyer and Klemkosky concluded that the "option markets appear to be efficient to the arbitrageur using the trading rules involving Black-Scholes and Roll pricing models" (p.119).

In another test of the efficiency of the CBOE, Krausz(1985), using the Black-Scholes model with Merton's dividend adjustment, also found that there were "no abnormal profit possibilities that may be exploited by hedging strategies" (p.893). Daily, weekly and monthly data for the period January 1977 to January 1979 were used.

Black and Scholes(1972) also used a hedging strategy, but they studied the efficiency of the over-the-counter options market in the US instead. The options data was obtained from the diaries of an option broker from 1966 to 1969. The share prices were daily closing prices. The Black-Scholes model was used to compute model prices using the variance computed from historical stock prices.

They found that by using historical stock prices to estimate the variance, options on stocks with high variances were underpriced (model > market) and options on stocks with low variances were over-priced (model < market). However, they found that the profits from a strategy of buying options on high variance stocks and selling options on low variance stocks were lower than the transactions costs estimated by them. Hence, they concluded that "even though the option market does not appear to be efficient before taking account of transaction costs, there is no opportunity for other traders to take advantage of this mispricing" (p.417).

Castagna and Matolcsy(1982) tested the efficiency of the Australian traded options market using a hedging strategy. The data sample consisted of daily closing share and option prices from the inception of the market in February 1976 to 30 September 1977.

The Black-Scholes model, adjusted for dividends by subtracting the present value of the expected dividends during the life of the option from the share price, was used to compute option model values. Three different estimators of the standard deviation of the stock's return were used as input to the model.

An <u>ex post</u> test was employed and hedges were held till maturity with the original long or short positions being maintained. The hedges were rebalanced daily to reflect changes in the hedge ratio.

The results indicated the existence of significant average excess returns which were eliminated when transactions costs were considered. Castagna and Matolcsy concluded that "the Australian traded options market is efficient" (p.531).

Van der Hilst(1980) studied the efficiency of the EOE using the Black-Scholes model and daily closing data for the year 1979, sub-divided into three sample periods. The variance input into the model was computed from the daily share prices of each of the sub-periods.

An ex post test was conducted where a hedge was set up immediately upon observing a mispricing. The hedge was liquidated one day later and the hedge return computed. Transactions costs were ignored.

The results showed that the EOE was not completely efficient during the period studied. However, since transactions costs were ignored, this result must be viewed with caution.

3.3 Results of spreading tests

Galai(1977) tested the efficiency of the CBOE with a spreading strategy. Relatively over-priced options were sold and relatively under-priced options, on the same stock and with the same striking price but of different maturity were bought. The *ex post* spreading test showed that the Black-Scholes model was able to differentiate, on average, between over-priced and under-priced options. This confirmed the results of his hedging test given in the previous section of this chapter. The *ex ante* spreading test yielded, on average, lower returns than the *ex post* test but the average returns were still significantly different from zero at the five per cent level. This also confirmed the results of the hedging test. However, Phillips and Smith(1980) showed that their estimated bid-ask spread cost for one call was sufficient to eliminate Galai's average profit.

Chiras and Manaster(1978) also used a spreading strategy to test the efficiency of the CBOE. They used the Black-Scholes model with Merton's dividend adjustment and monthly data for the period beginning June 1973 and ending April 1975.

Risk-free spreads were created by buying the most under-priced option and writing the most over-priced option on the same stock provided that in each case the model value deviated from the market price by at least ten per cent. The spreads were set up immediately upon observing a mispriced situation, that is, an _ex post_ test, and liquidated one month later. This spreading strategy produced an average monthly return of 9.96 per cent. Chiras and Manaster concluded that "the CBOE was inefficient during the period covered by this study" (p.231).

However, they cautioned that their result may be due to the potential problem of non-simultaneity of option prices. Bookstaber(1981) checked the Chiras and Manaster data for non-simultaneity and found that there was strong support for the concern that "the observed profits were due to the non-contemparoneous data, and are not achievable in practice" (p.155). In addition, Phillips and Smith(1980) showed that by introducing transactions costs, especially the bid-ask spread, the profits of the Chiras and Manaster study were eliminated.

In order to overcome the non-simultaneity problem associated with daily closing prices, Bhattacharya(1983) used transactions data to test the efficiency of the CBOE. The transactions data included every reported transaction and every reported bid-ask quote for each option. The sample period for the study was 196 trading days from 24 August 1976 to 12 June 1977. The Black-Scholes model with discrete dividend adjustment was used in his study.

His <u>ex ante</u> spreading test required spreads to be set up with the next available prices after the mispricing signals were observed. The spreads were held until maturity or until the mispricings were eliminated. They were rebalanced fortnightly with an average of 1.38 revisions over their lifetime. This test produced after transactions costs profits that would imply market inefficiency. However, Bhattacharya noted that his fortnightly revision of spreads could not maintain riskless positions and hence this result must be treated with caution.

French and Henderson(1981) used a substitute hedging strategy to study the efficiency of the CBOE and the American Stock Exchange options market. A substitute hedge is similar to a spread in that it consists of one under-valued (model > market) option and one over-valued (model < market) option where the under-valued option is bought and the over-valued option is written. It is different from a spread in that the two options are not written on the same stock. French and Henderson developed a hedge ratio which established a theoretically riskless substitute hedge.

Their data sample consisted of month-end closing stock and option prices for the period from the last day of May 1976 to the last day of December 1977, a total of twenty sample dates. The Black-Scholes model with Merton's dividend adjustment was used to compute model values for options. On each sample date, riskless substitute hedges were set up and these hedges were liquidated one month later. An *ex post* trading strategy was employed. It was found that over the period of study, returns in excess of the risk-free interest rate were possible, indicating that the options markets were less than efficient. However, when commissions were taken into account, the mean after-commission substitute hedge return was zero. French and Henderson concluded that "arbitrage opportunities existed that would allow a sophisticated commissionless trader to make an economic profit" (p.30). However, they cautioned that "it is questionable whether such returns would be attainable in practice" (p.30).

In the UK, option markets efficiency tests have been conducted by Kerruish(1984) and Gemmill and Dickins(1986).

Kerruish(1984) used the Black-Scholes model with two methods of adjusting for dividends, various estimators of the standard deviation of the underlying stock's return, and two methods of dealing with the bid-ask spread. The data sample consisted of daily closing stock and option prices for the period beginning July 1981 and ending in July 1982.

An ex post spreading test was used with the spreads being liquidated when one option price returned to its equilibrium value or when the mispricing was reversed, or when one option reached maturity. The spreads were rebalanced daily.

Kerruish found that the overall returns from spreading were not significantly greater than zero and concluded that the London Traded Options Market (LTOM) was efficient during the period studied.

Gemmill and Dickins(1986) also used ex post tests and a spreading strategy to test the efficiency of the LTOM. The data sample consisted of monthly stock and option closing prices from May 1978 to July 1983. The Black-Scholes model with the Chiras and Manaster weighted implied standard deviation was used to compute option model values .

Gemmill and Dickins found statistically significant profits in excess of the risk-free interest rate, indicating that the Black-Scholes model was able to identify over-priced and under-priced call options. However, these profits turned into losses when an estimated bid-ask spread was applied, and therefore the market could not be said to be inefficient.

3.4 Results of lower boundary condition tests

Galai(1978) tested for violations of the lower boundary condition for CBOE options and the ability to earn above-normal profits by exploiting these violations. For an American call with no dividend protection, Galai showed that the lower boundary condition is :

$$C(S,T,X,D) \geq \text{Max}\{0, \max_i [S - Ke^{-rT_i} - \sum_{j<i} D_{t_j} e^{-rT_j}], \quad S - Ke^{-rT} - \sum_{i=1}^{n} D_{t_i} e^{-rT_i}\}$$

where C(.) is the value of the unprotected American call, S is the price of the underlying share, T is the time to expiry of the option, X is the exercise price, $D = D_{t_1}, D_{t_2}, \ldots D_{t_n}$ is the vector of the n known dividends and $T_1, T_2, \ldots T_n$ are the n known periods to dividend payment days.

An <u>ex post</u> test and an <u>ex ante</u> test were performed mainly with data consisting of daily prices for each option traded on the CBOE for 152 trading days from 26 April 1973 to 30 November 1973. A limited test was carried out on transaction-by-transaction prices of a few options traded during 1973.

The results of the *ex post* test using daily closing prices showed that there were frequent violations of the lower boundary condition and that their magnitudes were not trivial. Tests using transaction-by-transaction data yielded similar results, leading to rejection of the hypothesis that stock and option markets were sufficiently synchronized.

When a trader observed a violation of the lower boundary condition, he had to place orders in the markets to exploit what seemed to be a profit opportunity. This takes time and there is no guarantee that prices at the next available transaction will enable the trader to earn the profit he observed earlier. Hence, to determine whether the observed violations can be exploited to earn above-normal profits, indicating market inefficiency, Galai carried out an *ex ante* test.

The results of the *ex ante* test showed that profits were substantially reduced. However, on average, above-normal profits could still be earned. Phillips and Smith(1980) showed that this profit will be eliminated when transactions costs, in particular the bid-ask spread, were taken into account. Hence, the

CBOE was not inefficient.

Bhattacharya(1983) also tested the possibility of making above-normal profits by exploiting violations of lower boundary conditions for CBOE options. Galai's lower boundary condition was modified to incorporate the bid and ask prices for stock and options. The data sample consisted of transactions data for 196 trading days from 24 August 1976 to 12 June 1977.

Bhattacharya's ex ante test produced an average profit of $8.20 per contract for the zero transactions costs case. This profit changed to a loss of $8.63 per contract when transactions costs of an option market maker were taken into account. Hence, the hypothesis of market efficiency cannot be rejected.

Halpern and Turnbull(1985) also conducted tests of lower boundary conditions using transactions data. However, they studied the Toronto Stock Exchange (TSE) options market instead. The data sample consisted of records of every options transaction on the TSE from 3 January 1978 to 31 December 1979.

They found that violations of the lower boundary condition did occur and their results indicated that the TSE options market was inefficient during the period studied, even when transactions costs were taken into account. However, they cautioned that the high growth experienced in the sample period was not typical, and therefore that " observed inefficiencies shoud not be generalised to current periods where the options market has matured and its growth has levelled off" (p.500).

3.5 Results of convexity condition test

Galai(1979) tested the convexity condition for CBOE options. The Merton(1973a) convexity condition for European calls showed that the premium of a call is a declining convex function of the exercise price. Merton's proof is also valid for an American call if it is dividend-protected. However, CBOE calls are not dividend-protected. Galai proved that Merton's convexity condition applies to CBOE options too. The convexity condition stated that three options written on the same underlying stock, with the same expiration date but with different exercise prices, should be priced such that :

$$aC_1 + (1 - a)C_3 > C_2$$

where C_1, C_2 and C_3 are the prices of the three options with exercise prices K_1, K_2 and K_3 respectively, such that $K_1 < K_2 < K_3$, and $a=(K_3 - K_2) / (K_3 - K_1)$.

Using daily closing data for the period 26 April 1973 to 30 October 1973, Galai found twenty four violations of the convexity condition out of a total of one thousand observations. The examination of transaction-by-transaction data for the three options involved in each violation revealed that most of the observed violations appeared for closing prices only, and could not be detected during the day. Quite often, the closing prices reflected transactions that took place during different hours of the day and "what looks like a profit opportunity can be an illusion caused by the procedures used in reporting the closing prices" (p.87). With this evidence, it is quite obvious that ex ante tests were unnecessary and the market cannot be said to be inefficient.

Bhattacharya(1983) also tested the convexity condition for CBOE options using transactions data. Bid and ask prices were incorporated into the convexity condition. Only one violation of the convexity condition was found among the 1006 triplets of options written on the same stock and with identical maturity. He concluded that the hypothesis of efficiency cannot be rejected.

3.6 Results of Put-Call Parity Tests

Stoll(1969) developed the original put-call parity model which was later extended by Merton(1973b). Based on Stoll's analysis, the following relationship between put and call prices must hold in a 'frictionless' market at equilibrium :

$$C - P = S - X / (1 + r) \qquad (1)$$

where C = current market price of a European call,

P = current market price of a European put,

S = current market price of the underlying stock,

X = exercise price of the call and the put,

r = risk-free interest rate.

Stoll did not differentiate between European and American options and in essence implied that (1) holds regardless of the type of options used in constructing the hedges. However, Merton(1973b), in a comment on Stoll's paper, showed that (1) holds for European options only. Stoll(1973), in reply to Merton, conceded the point but argued that the conditions under which early exercise would occur were not likely to happen.

Merton suggested that the best that can be done for dividend-protected American options are the bounding inequalities :

$$S - X \leq C - P_a \leq S - X / (1 + r)$$

where P_a is the current market price of an American put.

Stoll(1969) also empirically tested the put-call parity model for over-the-counter put and call options. The data sample included 1966 and 1967 put and call prices submitted weekly by the Put and Call Dealers Association to the Securities and Exchange Commission. In this sample, there were ten "regular" companies for which put and call prices were quoted every week and ten "new business" companies which changed weekly and presumably represented stocks with the greatest amount of activity. Hence, only companies with a relatively active option market were included in the sample. Stoll's results showed that "by and large the theory is supported by the time series and cross section regression analysis carried out" (p.823).

Gould and Galai(1974) tested the put-call parity model with modifications by Merton(1973b). Using the Stoll(1969) data sample expanded to include 1968 and 1969 data provided by Black and Scholes, they found a surprising number of violations of the modified put-call parity model for at-the-money options, that is, $(C - P_a)/S \leq r/(1+r)$. These violations represented potential profit opportunities, which disappeared when transactions costs for non-members of the exchange are considered. However, they found that a member of the New York Stock Exchange could have exploited these profit opportunities and that these profit opportunities persisted over time. Also, tests with the Black-Scholes data sample supported these findings. However, these profit opportunities were determined ex post. It is not known whether they would still be available if a time lag is allowed for before a trader enters into a transaction to exploit them. In addition, the authors cautioned that "the put and call market is not organised as well as the market for common stocks and other securities and the costs of finding buyers and sellers may be higher than we think" (p.123).

Klemkosky and Resnick(1979) derived the put-call parity conditions for exchange-traded dividend-unprotected American options. These conditions were tested using transactions data for one day each month during the period July 1977 to June 1978 for fifteen companies with puts and calls listed on the CBOE, the American and the Philadelphia Stock Exchanges. This data sample made it possible to construct a nearly simultaneous position in the call, the put and the underlying stock. The study required that the call, the put and the underlying stock all had to trade within one minute of each other.

Klemkosky and Resnick found 234 (about forty per cent) profitable hedges out of a total of 540. However, when an estimated transactions cost of twenty dollars for a member firm was introduced, only 147 (27 per cent) hedges out of the 540 remained profitable. With a sixty dollars transactions costs for non-member investors, the number of profitable hedges is reduced to 38 (seven per cent). They concluded that "the empirical results of the models tested are consistent with put-call parity theory and thus support this aspect of efficiency for registered options markets" (p.1154).

Klemkosky and Resnick(1980) extended their previous work by conducting <u>ex ante</u> tests of the put-call parity model. In the <u>ex ante</u> test, two lags were tested. The execution of hedges were lagged by (i) five minutes and (ii) fifteen minutes after they had been initially identified as having <u>ex post</u> returns in excess of twenty per hedge. The results showed that <u>ex ante</u> profits were available. However, these tended to be lower than the <u>ex post</u> profits. When the bid-ask spread was included in each position, most of the profits were eliminated. They concluded that "price correction appears to take place rapidly enough on the registered options exchanges to eliminate most if not all of the economic profits for an arbitraging member firm" (p.372).

Loudon(1988) provided Australian evidence on the put-call parity theorem. He found that the sizes of most of the violations of the put-call parity theorem were quite small, with only one violation exceeding transactions costs. He concluded that "observed violations of the put-call parity theorem were not sufficiently large to suggest that there existed potential for investors facing normal transactions costs to generate economic profits" (p.65).

3.7 Results of volatility tests

Maloney and Rogalski(1989) tested the efficiency of the Chicago Board Options Exchange by determining whether equity call option prices reflect, ex ante, the higher variability of stock returns in January, as documented by Rogalski and Tinic(1986).

They found that "during the last six weeks of the calendar year, implied volatility estimates from market call prices trend upward" and that "after the turn of the year, implied volatility estimates decline" (p.551).

They concluded that their evidence is "consistent with the prediction of an efficient option market that anticipates higher than average volatility around the turn of the year and incorporates that expectation into market call prices" (p.551).

Sheikh(1989) observed that Dravid(1984), Ohlson and Penman(1985) and Dubofsky and French(1985) have documented significant increases in the variance of common stock returns subsequent to splits of larger than 25 per cent. He tested the efficiency of the Chicago Board Options Exchange by examining the announcement and ex-date behaviour of stock return volatilities implied by call prices of options written on stocks that announced a split. The question addressed is whether the implied volatilities of stocks that announced a split increase relative to the implied volatilities of other stocks.

His study found no evidence of such an increase at the announcement date. However, a relative increase is detected at the ex-date, showing that the Chicago Board Options Exchange did not anticipate post-split increases in stock return volatilities till the ex-date. It was further shown that "the ex-date increase in implied variances translates into excess returns to market-makers" (p.1371), therefore implying that the Chicago Board Options Exchange was not efficient. However, it must be noted that the excess returns were computed under the assumption that the market-makers not only need not pay the bid-ask spread cost but can in fact earn the spread. Sheikh noted that "this may not be possible and then their returns could be similar to those of arbitrageurs" (p.1369). Returns of arbitrageurs have been shown to be insignificantly different from zero.

3.8 Summary

This chapter reviewed the evidence on stock options market efficiency. Evidence on the efficiency of stock options markets in the US, UK, Australia, Canada and the Netherlands was presented.

In general, it seemed that while there were abnormal profit opportunities before transactions costs were taken into account, these profits were eliminated once they were adjusted for transactions costs. Hence, the hypothesis of efficiency cannot be rejected.

References

Bhattacharya, M. "Transactions Data Test of Efficiency of Chicago Board Options Exchange", **Journal of Financial Economics**, 1983 pp161-185

Black, F. and Scholes, M. "The Valuation of Option Contracts and a Test of Market Efficiency", **Journal of Finance**, 1972 pp399-417

Blomeyer, E. C. and Klemkosky, R. C. "Tests of Market Efficiency for American Call Options", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath and Co., Lexington Books, 1983

Bookstaber, R. "Observed Option Mispricing and the Nonsimultaneity of Stock and Option Quotations", **Journal of Business**, 1981 pp141-155

Castagna, A. D. and Matolcsy, Z. P. "A Two Stage Experimental Design to Test the Efficiency of the Markets for Traded Options and the Australian Evidence", **Journal of Banking and Finance**, 1982 pp521-532

Chiras, D. and Manaster, S. "The Information Content of Option Prices and a Test of Market Efficiency", **Journal of Financial Economics**, 1978 pp213-234

Dravid, A. R. "The Behaviour of Returns around Ex-dates for Splits and Stock Dividends", **Working Paper, Stanford University**, 1984

Dubofsky, D. and French, D. "More on the Increase in Volatility Subsequent to Stock Splits", **Working Paper, Texas A and M University and Texas Christian University**, 1985

French, D. W. and Henderson, G. V. "Substitute Hedged Option Portfolios : Theory and Evidence", **Journal of Financial Research**, Spring 1981 pp21-31

Galai, D. "Tests of Market Efficiency of the Chicago Board Options Exchange", **Journal of Business**, 1977 pp167-197

Galai, D. "Empirical Tests of Boundary Conditions for CBOE Options", **Journal of Financial Economics**, 1978 pp187-211

Galai, D. "A Convexity Test for Traded Options", **Quarterly Review of Business and Economics**, 1979 pp83-90

Gemmill, G. and Dickins, P. "An Examination of the Efficiency of the London Traded Options Market", **Applied Economics**, 1986 pp995-1010

Gould, J. and Galai, D. "Transactions Costs and the Relationship Between Put and Call Prices", **Journal of Financial Economics**, 1974 pp105-129

Halpern, P. and Turnbull, S. "Empirical Tests of Boundary Conditions for Toronto Stock Exchange Options", **Journal of Finance**, 1985 pp481-500

Kerruish, A. "An Empirical Test of the Black-Scholes Option Pricing Model in the UK and Implications for Market Efficiency", Presented to the **European Finance Association Meeting**, September 1985

Klemkosky, R. C. and Resnick, B. G. "Put-call Parity and Market Efficiency", **Journal of Finance**, 1979 pp1141-1155

Klemkosky, R. C. and Resnick, B. G. "An Ex-Ante Analysis of Put-Call Parity", **Journal of Financial Economics**, 1980 pp363-378

Krausz, J. "Option Parameter Analysis and Market Efficiency Tests : A Simultaneous Solution Approach", **Applied Economics**, 1985 pp885-896

Loudon, G. F. "Put Call Parity Theory : Evidence from the Big Australian", **Australian Journal of Management**, June 1988 pp53-67

Maloney, K. J. and Rogalski, R. "Call Option Pricing and the Turn of the Year", **Journal of Business**, 1989 pp539-552

Merton, R. C. "Theory of Rational Option Pricing", **Bell Journal of Economics and Management Science**, 1973a pp141-183

Merton, R. C. "The Relationship Between Put and Call Option Prices : Comment", **Journal of Finance**, 1973b pp183-184

Ohlson, J. and Penman, S. "Volatility Increases Subsequent to Stock Splits : An Empirical Aberration", **Journal of Financial Economics**, 1985 pp251-266

Phillips, S. and Smith, C. "Trading Costs for Listed Options: The Implications for Market Efficiency", **Journal of Financial Economics**, 1980 pp179-201

Rogalski, R. and Tinic, S. "The January Size Effect : Anomaly or Risk Mismeasurement ?", **Financial Analysts Journal**, November-December 1986 pp63-70

Sheikh, A. M. "Stock Splits, Volatility Increases and Implied Volatilities", **Journal of Finance**, 1989 pp1361-1372

Stoll, H. R. "The Relationship Between Put and Call Option Prices", **Journal of Finance**, 1969 pp 801-822

Stoll, H. R. "The Relationship Between Put and Call Option Prices : Reply", **Journal of Finance**, 1973 pp185-187

Van der Hilst, J. "Marktefficiency op de EOE te Amsterdam", in **Financiering en Belegging**, stand van zaken anno 1980, Ballendux, F. J. (ed), Erasmus Universiteit, Rotterdam (1980)

Chapter 4

Methodology

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Methodology

4.1 Introduction

The objective of this study is to provide evidence on the efficiency or otherwise of the stock options market of the European Options Exchange.

This chapter reviews the methodological issues associated with tests of options market efficiency and describes the methodology used in this study. One major issue discussed is the choice of estimators for the standard deviation of the underlying stock's return. This is followed by descriptions of the types of tests carried out, the trading strategies used, the criteria used for determining mispriced options and the method of calculating the rate of return. The problems related to the incorporation of the bid-ask spread cost into the tests and the possibility of premature exercise of options are also addressed, together with the limitations inherent in the daily rebalancing of spreads and hedges.

4.2 Estimators for the Volatility of a Stock's Return

The original Black-Scholes model requires five inputs : the underlying share price, the risk-free interest rate, the time to expiry of the option, the exercise price and the standard deviation of the returns on the underlying stock during the remaining life of the option.

Of all these inputs to the model, the most difficult item to measure is the standard deviation of the stock's return. The underlying share price at the close of the market can be observed, the risk-free interest rate can be estimated by computing the yield on government securities with the same time to maturity, the time to maturity is easily computed from the expiration date and the current date, and the exercise price is given. The standard deviation cannot be obtained from newspapers, nor calculated, because the standard deviation of interest is the future standard deviation between the current day and the expiration day. This input has to be estimated. The importance of an accurate estimation of the standard deviation was highlighted by Black and Scholes (1972). They noted that "if the model has an accurate estimate of the variance, it works very well..... More work must be done to predict variances using the information available" (p.416).

Various estimators of the standard deviation of the stock's return have been used in previous empirical works. These include :

a) Historical standard deviation (Gemmill(1986),Chiras and Manaster(1978) and Latane and Rendleman(1976)),

b) Chiras and Manaster's weighted implied standard deviation (Chiras and Manaster(1978) and Gemmill and Dickins(1986) and Blomeyer and Klemkosky(1983)),

c) Latane and Rendleman's weighted implied standard deviation (Latane and Rendleman(1976), Latane and Rendleman(1979) and Beckers(1981)),

d) Arithmetic mean of the implied standard deviations of all options of the same class (Kerruish(1984) and Chiras and Manaster(1978)),

e) Beckers' weighted implied standard deviation (Beckers(1981)),

f) Implied standard deviation of the at-the-money option (Macbeth and Merville(1979)),

g) Implied standard deviation of the most out-of-the-money option (Gemmill(1986)),

h) Implied standard deviation of the most in-the-money option (Gemmill(1986)),

i) Implied standard deviation of the option that is most sensitive to changes in the standard deviation of the underlying stock (that is, the option with the highest $\delta C/\delta\sigma$ (Beckers(1981)),

j) Arithmetic mean of the options nearest to or at-the-money and the two options on either side in terms of exercise prices, provided they are of medium or long term duration (that is, greater than ninety days) (Kerruish(1984)),

k) Arithmetic mean of the options nearest to or at-the-money and the two options on either side in terms of exercise prices, provided they are of medium term maturity (that is, greater than ninety days but less than one hundred and eighty days) (Kerruish(1984)),

l) Black's estimator (Beckers(1981) and Cox and Rubinstein(1985)) and

m) DATASTREAM's estimator (DATASTREAM Traded Options Services User Manual).

Out of this list of thirteen estimators, three (items (b), (i) and (m)) are selected for testing in this study. The reasons for selecting these three estimators and rejecting the others are given below. Five of the estimators do not seem to have any theoretical justification. These are items (d), (g), (h), (j) and (k) and they are not tested in this study.

In the case of item (d), there is no justification for each of the implied standard deviations to be given equal weights to obtain the weighted implied standard deviation. The reason given for its use is that it is a convenient way to combine all the individual implied standard deviations into a weighted implied standard deviation. For example, Gemmill(1986) described this estimator as a "much simpler way to combine the implied standard deviations into a single estimate" (p.538).

Items (j) and (k) were used by Kerruish(1984). Kerruish excluded deep-in and deep-out-of-the-money options on the grounds that Merton(1976) provided evidence on the inaccuracy of the Black-Scholes model in valuing these options when the underlying stock returns are not continuous. However, she is unclear about how the implied standard deviations were combined into a single estimate and no justifications were given for any method used.

Items (g) and (h) were tested by Gemmill(1986). Gemmill did not provide any reasons for his choice. There are no theoretical justifications for these two estimators.

Item (a) is the historical standard deviation. This item is the standard deviation of a series of past logarithmic stock returns. To obtain an unbiased estimator of the population standard deviation, a correction factor of n/(n-1) is applied to the variance so that

$$\sigma^2 = (1/(n-1))\Sigma(\log R_j - u)^2$$

where σ^2 = unbiased estimated variance of the logarithmic stock returns,

R_j = stock returns (final stock price divided by initial stock price),

u = estimated mean of the logarithmic stock returns (that is, $(1/n)\Sigma \log R_j$) and

n = number of stock returns.

The unbiased standard deviation is approximately the square root of σ^2 (Cox and Rubinstein(1985) p.256).

If the true standard deviation is constant over time, as is assumed in the Black-Scholes model, then the historical standard deviation would have been a good estimator of the true standard deviation. Unfortunately, this Black-Scholes model assumption is not a good approximation of reality. Some evidence of this for stocks with options traded on the EOE can be found in Kemna(1987). Kemna subdivided her sample of twenty weeks into two subsamples of ten weeks each. The average implied standard deviations of each stock for the two subsamples are then compared. She found that "for most stocks the average implied standard deviation over the first ten weeks is not equal to the average implied standard deviation over the second ten weeks, which leads to the conclusion that over these time periods the implied standard deviation is not constant" (p.12).

Chiras and Manaster(1978) and Latane and

Rendleman(1976) provided evidence to show that the implied standard deviation of the stock's return is superior to the historical standard deviation as a predictor of the true standard deviation. Chiras and Manaster(1978) tested the following hypothesis : "Standard deviations inferred from option prices have been better predictors of standard deviations of future stock returns than standard deviations obtained from historic stock returns" (p.218). They regressed the actual standard deviation on the historical standard deviation, and also regressed the actual standard standard deviation on their weighted implied standard deviation for twenty three stocks with twenty three monthly observations each. For the monthly regression, the average R^2 (over the twenty three months) was 0.26 for the first regression and 0.32 for the second regression. For the 'grand regression', where all observations were pooled, they found that the R^2 was 0.31 compared to 0.63 for the second regression. Hence, they concluded that "the WISDs have been substantially better predictors of SDFUTs than have the SDHISTs" (p.226). WISD refers to their weighted implied standard deviation, SDFUT refers to the actual standard deviation of the stock's return over the remaining life of the option, and SDHIST refers to the historical standard deviation of the stock's return.

Latane and Rendleman(1976) found that the correlation (0.823) between their weighted implied standard deviation and the actual standard deviation is much stronger than the correlation (0.558) between the historical standard deviation and the actual standard deviation. They concluded that "the weighted implied standard deviation is generally a better predictor of future variability than standard deviation predictors based on historical data" (p.381).

Chiras and Manaster(1978) and Latane and Rendleman(1976) both found the weighted implied standard deviation to be superior to the historical standard deviation. The weighted implied standard deviation was superior even though they used different weighting systems. If the market uses only the past time series of stock returns to estimate future standard deviations, then the weighted implied standard deviations could not have been found to be superior. It is possible that the market uses more information than merely the past time series of stock returns in assessing the future standard deviation. Given this evidence, the historical standard deviation will not be tested in this study.

The historical standard deviation had been used by Galai(1977) and Trippi(1977) as an estimator of the standard deviation of a stock's return. Latane and Rendleman(1976), on the other hand, used a different approach. They equated the Black-Scholes model price to the market price of the option to solve for the implied standard deviation of the stock's return. Since the implied standard deviation is obtained from the market price of the option, it represents the market's assessment of the future standard deviation of the stock's return. However, in practice not all options written on a particular stock would be priced with the same standard deviation of the stock's return. This is because some options' prices are more sensitive to a precise specification of the standard deviation than others. The implied standard deviations on those options whose prices are least sensitive to a precise specification of the standard deviation are likely to be unrepresentative of the market's underlying expectations. Implied standard deviations on such options could take on a wide range of values within a narrow range of option prices, so that minor errors in the recording of the option prices could result in major errors in the implied standard deviation. Accordingly, implied standard deviations of such options should not be given as much weight as implied standard deviations of options in which the standard deviation is a more important factor. Latane and Rendleman therefore proposed a weighted implied standard deviation, in which the weights of the implied standard deviations are given by the partial derivative of the Black-Scholes equation with respect to each implied standard deviation. Latane and Rendleman(1979) gave the weighting system as :

$$WISD_{it} = (\sum_{j=1}^{N} ISD_{ijt}^2 \, d_{ijt}^2)^{0.5} \, (\sum_{j=1}^{N} d_{ijt}^2)^{-0.5}$$

where $WISD_{it}$ = WISD for company i in period t,

ISD_{ijt} = ISD for option j of company i in period t,

N = number of options analysed for company i and is always greater than or equal to two and

d_{ijt} = partial derivation of the price of option j of company i in period t with respect to its implied standard deviation using the Black-Scholes model.

This weighted implied standard deviation is item (c) in the list above.

Chiras and Manaster(1978) also used a weighted implied standard deviation rather than the historical standard deviation. However, they weighted the implied standard deviations according to the price elasticities of the option with respect to their implied standard deviation. They argued that the Latane and Rendleman weighting scheme emphasised the total dollar return without regard to the size of the investment : it weighted implied standard deviations according to the dollar price change for the options relative to the incremental change in the implied standard deviation. A rational investor measures return as the ratio of the dollar price change to the size of the investment. Therefore, weighting implied standard deviations according to the price elasticity of the option with respect to their implied standard deviation is consistent with a rational measure of returns, because the price elasticity measures the percentage change in the price of an option with respect to the percentage change in its implied standard deviation. Chiras and Manaster's weighted implied standard deviation is

$$WISD = \left(\sum_{j=1}^{N} ISD_j (\delta w_j/\delta v_j)(v_j/w_j)\right) \Big/ \left(\sum_{j=1}^{N} (\delta w_j/\delta v_j)(v_j/w_j)\right)$$

where N = the number of options recorded on a particular stock for the observation date,

ISD_j = the implied standard deviation of option j

$(\delta w_j/\delta v_j)(v_j/w_j)$ = the price elasticity of option j with respect to its implied standard deviation.

Beckers(1981) proposed two other estimators for the standard deviation of the stock's return. One estimator (item (i)) is the implied standard deviation of the option whose value is most sensitive to changes in its implied standard deviation. Beckers observed that this is usually the option that is only slightly out-of-the-money; hence, Beckers referred to this as the at-the-money option (AMISD). The justification for using this estimator is that "all available information should be reflected in the at-the-money option and that other option prices had too much noise to be of any relevance" (Beckers(1981) p.370). Also, Black(1975) had noted that there is a tendency for the Black-Scholes model to work poorly for deep-in-the-money and deep-out-of-money options. Therefore, if implied standard deviations of these options are imputed from the Black-Scholes model, inclusion of these implied standard deviations in the computation of a weighted implied standard deviation could worsen its predictive ability relative to that of the AMISD. The other estimator proposed by Beckers (item (e)) is obtained by searching for the implied standard deviation that minimizes the following "loss function" :

$$f(ISD) = \sum_{i=1}^{I} W_i (C_i - BS_i(ISD))^2 / \sum_{i=1}^{I} W_i$$

where C_i = market price of option i,

BS_i = Black-Scholes option price as a function of the implied standard deviation,

I = total number of options on a given stock with the same maturity and

W_i = weight for the ith option = $\delta BS_i(ISD)/\delta ISD$ (that is, the first derivative of the Black-Scholes formula with respect to the standard deviation).

Beckers argued that this procedure will produce an estimator that puts "more weight on options that are highly sensitive to an exact specification of the standard deviation" (p.370) as the actual weights in this procedure "are proportional to the squared values of the Latane and Rendleman weights" (p.370).

Beckers found that the AMISD out-performed both the Latane and Rendleman weighted implied standard deviation and his own weighted implied standard deviation obtained from minimising his "loss function". In the case of Beckers' own weighted implied standard deviation, the AMISD out-performed it in seven out of ten cases, that is, the R^2 of the regression of the actual standard deviation of the stock's return over the remaining life of the option (SSD) on AMISD is higher than the R^2 of the regression of the SSD on Beckers' weighted implied standard deviation in seven out of ten cases. Beckers' results confirmed that the use of weighting schemes, and in particular Latane and Rendleman's and Beckers' own schemes, worsens the predictive ability (R^2) of the estimator. Hence, the Latane and Rendleman estimator and Beckers' estimator will not be tested in this study. Beckers, however, did not test the AMISD against the Chiras and Manaster estimator. Therefore, in this study the AMISD and the Chiras and Manaster estimator will be used.

The implied standard deviation of the at-the-money option (item (f)) has been used by Macbeth and Merville(1979). The problem with this estimator is that there is usually no option that is exactly at-the-money. Hence, the implied standard deviation for the at-the-money option cannot be observed. To overcome this problem, Macbeth and Merville used a regression model to deduce the implied standard deviation of the at-the-money option. The regression model is

$$\sigma_{ijt} = \theta_{i0t} + \theta_{i1t}M_{ijt} + \varepsilon_{ijt} \qquad j = 1,2,\ldots J$$

where σ_{ijt} is the implied standard deviation for option j on stock i on day t and

$$M_{ijt} = (S_{it} - X_{ij}e^{-rT}) / X_{ij}e^{-rT}$$

where S_{it} is the closing price of stock i on day t and $X_{ij}e^{-rT}$ is the present value at time t of the exercise price of option j on stock i. For an at-the-money option, S_{it} equals $X_{ij}e^{-rT}$, so that M_{ijt} equals zero. Therefore, the estimated implied standard deviation for the at-the-money option on stock i at day t is the value of θ_{i0t}.

The problem with this regression model is that there are, in most cases, very few observations for each regression. Macbeth and Merville had an average of five observations. In this study, the number of options per maturity per stock is also around five. With few observations, the estimates of θ_0 and θ_1 will be unreliable. Moreover, this at-the-money implied standard deviation is likely to be close to the AMISD because Beckers(1981) observed that the AMISD is usually the implied standard deviation of the option that is slightly out-of-the-money. Hence, item (f) will not be tested in this study.

Item (l) refers to Black's estimator. Cox and Rubinstein(1985) provided some insight into how Black's estimator is obtained. Black combined information from historical stock prices with an option's implied volatility, and empirical knowledge about how volatilities change over time, to obtain his estimates of a stock's volatility. He took into account four observations :

1) Volatilities of different stocks tend to change together in the same direction,
2) Changes in volatilities are often temporary; after a significant change up or down, volatilities seem to revert back toward their previous levels,
3) Changes in stock prices not caused by stock splits or stock dividends are inversely related to changes in their associated volatilities and
4) An option's implicit volatility contains useful

information for predicting the true volatility of its associated stock.

Black incorporated these observations into his estimator. In addition, Black sometimes used his judgement to adjust his estimates up or down.

Beckers(1981) tested Black's estimates of volatility, obtained from Black's Option Pricing Service, against Beckers own weighted implied standard deviation (item (e)) and the implied standard deviation of the option that is most sensitive to changes in the standard deviation of the underlying stock (item (i)). He found that Black's estimator out-performed item (e) and item (i) in seven out ten cases : the R^2 from the regressions of the actual standard deviation of the stock's return over the remaining life of the option (SSD) on Black's estimates were higher than the R^2 from the regressions of SSD on either item (e) or item (i) in seven out of ten cases. Beckers therefore concluded that "by including additional information in his prediction rule, Black is able to obtain better predictive results" (p.376). In spite of this evidence, Black's estimator will not be tested in this study because his estimates cannot always be computed mechanically; the exact prediction rule is not known and sometimes Black's judgement plays an important role in obtaining the estimates.

The final estimator of the stock's volatility to be considered is that used by DATASTREAM (hereinafter DSISD). The method of computation of the DSISD is described in Chapter Five. The DSISD incorporates both historical and implied volatility measures. This estimator will be tested in this study because DATASTREAM is widely subscribed to by the financial community, and it would be of interest to see how it performs.

In addition to the estimators considered above, Brenner and Galai(1984) suggested using transactions data instead of closing price data to impute the implied standard deviation of the underlying stock's return. Brenner and Galai reasoned that an ISD computed from transactions data will be superior to the ISD computed from closing prices, because closing prices might be manipulated by traders to reduce their overnight margin requirements, and also closing stock and option prices might be non-synchronous. They proposed a transactions' average implied standard deviation (AISD) computed as the average of all ISDs generated by transactions during the day. The AISD gives little weight to the last transaction of the day.

Using transactions data on IBM stock and options for the period 3 June 1977 to 21 October 1977, they found that the ISD computed from closing prices deviated significantly from the AISDs. They reasoned that for stocks less actively traded than IBM, the deviations are expected to be more pronounced. However, whatever the merits of the AISD, it will not be tested because transactions data is not used in this study.

No matter which estimator is used, it is more meaningful to compute one estimate of the stock's volatility for each maturity. This is because Kemna(1987) presented evidence that the stock's volatility may not be constant over time. If the stock's volatility is not constant over time, then options with differing maturities can be expected to generate different implied standard deviations. Moreover, the implied standard deviations of options with differing maturities may reflect "different perceptions of short run versus long run volatility" (Brenner and Subrahmanyam(1988) p.80).

Given the presumption that the volatility is not constant, the B-S model may be an inappropriate model to use since the model assumes that the volatility is constant. Beckers (1981) noted that there is a basic inconsistency in using the B-S model to obtain predictions of a presumably non-constant variance. However, he reasoned that the results of Latane and Rendleman(1976) "indicated that the approach is valuable, at least from a pragmatic standpoint" (p.364). Similarly Galai (1983b) noted that "the results of Latane and Rendleman (1976) and Schmalensee and Trippi (1978) indicate that the B-S model is still valuable in predicting future volatilities. It may be the case that the model is not very sensitive to violations of the non-stationarity assumption" (p.66).

4.3 Types of Tests

It is of interest to know whether the market is efficient to both those traders who are not permitted to trade on the floor of the exchange and those traders who are permitted to do so. The first group includes individual traders and some members of the exchange, for example, off-floor traders. The second group includes market-makers and floor-brokers.

It is important to distinguish between the two groups because the second group of traders may be able to transact almost immediately upon observing any mispriced situations. Bhattacharya(1983) stated that "it is conceivable that a market-maker recognises a mispriced option and trades immediately ..." (p.182). The first group can be expected to require a much longer time lag since they are not permitted to be physically present and to trade on the floor of the exchange. Their orders have to be passed through their brokers to the traders on the floor.

To examine the performance of these two groups of traders, four types of tests are conducted in this study : an ex post test with zero transactions costs, an ex ante test with zero transactions costs, an ex ante test with the bid-ask spread cost, and an ex post test with the bid-ask spread cost.

An ex post test is one in which the trading strategy determined with prices at time t is assumed to be implemented at time t. An ex ante test is one in which there is a time lag between formation of the strategy (at time t) and its implementation one period later (at time t+1). Thus, if an option is found to be mispriced at time t, it can only be bought (written) at time t+1. Similarly, if the mispricing of the option is reversed at time t+1, it can only be liquidated at time t+2. As daily data is used in this study, the minimum lag that can be built into the tests is one day. Thus, in the ex ante test, the time lag between the formation of the strategy and its execution is one day.

In the case of a trader who is not permitted to trade on the floor of the exchange, it is impossible for him to observe a mispricing and trade almost immediately, and so the ex post test is not appropriate. The ex ante test, with a one day time lag is used.

In the case of a trader who is permitted to trade on the floor of the exchange, it may be possible to observe a mis-pricing and trade almost instantaneously. The ex ante test in this study allows for a one day delay in execution of the spreads, as daily data is used. For such a trader, the ex ante test therefore overstates the delay in the execution of the spread. The ex post test may approximate the position of such a trader more closely.

The ex post test with zero transactions costs provides evidence of the ability of the trading rule to identify mis-priced options. The difference between the profits of the ex post test with zero transactions costs and ex ante test with zero transactions costs gives some indication of the extent to which market prices converge to model prices during the one-day lag. The ex ante test determines the extent to which the ability of the trading rule to identify mis-priced options can be exploited by a trader who is not permitted to trade on the floor of the exchange. The impact of the bid-ask spread cost can be observed from the difference between the profits of the tests with zero transactions costs, and the tests with the bid-ask spread cost.

4.4 Bid-ask Spread Cost

To test for the market's efficiency, returns after transactions costs will be computed to determine whether there are abnormal returns after transactions costs. As Jensen (1978) stated, market efficiency implies that economic profits from trading are zero, where economic profits are " risk-adjusted returns net of all costs" (p.96).

Transactions costs include not only commissions but also the bid-ask spread cost, information costs in identifying 'mispriced' options, and for market-makers the cost of a seat on the exchange. Phillips and Smith (1980) demonstrated the importance of taking into account all transactions costs in market efficiency tests. After estimating the bid-ask spread, they adjusted the reported returns of five previous studies of option market effficiency by deducting the estimated spread from the reported returns. All five studies had shown that their trading rules produce above-normal profits. However, Phillips and Smith showed that after taking into account the bid-ask spread, these profits were eliminated. For example, Galai (1977) reported a profit of $4.00 per spread per day for his ex ante spreading test, and concluded that the market did not seem perfectly efficient to market-makers. But Phillips and Smith showed that their estimated spread of $16.00 for one call was sufficient to offset Galai's $4.00 average profit. Phillips and Smith argued that a market-maker is not exempted from the bid-ask spread because, to actively establish a position in his own security, he must deal with the limit order book or a competing market-maker.

This study takes into account the bid-ask spread cost by assuming that options are bought at the ask price and written at the bid price. The bid-ask spread is therefore accounted for directly and there is no need to use an estimated average bid-ask spread. However, to assume that options are bought at the ask price and written at the bid price is to incorporate the whole of the bid-ask spread as transactions costs. In practice, transactions may occur within the quoted bid-ask spread, and this assumption will therefore tend to bias the results in favour of efficiency. However, this problem cannot be avoided as the true bid-ask spread is not known.

Roll(1984) developed a measure for estimating the effective bid-ask spread from a time series of past prices. The effective bid-ask spread is measured by $2\sqrt{-\text{cov}(\Delta P_t, \Delta P_{t+1})}$. The Roll model is extended by Choi, Salandro and Shastri(1988) by incorporating the possibility of serial correlation in transaction type. Their formula is as follows :

$$[\sqrt{-\text{cov}(\Delta P_t, \Delta P_{t+1})}] \;/\; (1-\delta)$$

where δ is the conditional probability that the transaction at time t+1 is at the bid (ask) price, given that the transaction at time t is at the bid (ask) price. Roll assumed that δ = 0.5. The derivation of both the Roll and Choi, Salandro and Shastri formulae requires the assumption that the asset is traded in an efficient market. As this study is concerned with providing evidence on the market's efficiency, it would not be appropriate to use their models to obtain estimates of the effective bid-ask spread.

4.5 Mispriced Options

This study uses a theoretically 'riskless' strategy to exploit any mis-pricing in the options. An option is assumed to be mis-priced when its market price deviates from the model value. For the zero transactions costs case, the model value is compared to the mid-market value, that is, the average of the bid and ask prices. When the bid-ask spread is to be taken into account as a transactions cost, it is assumed that options are bought at the market ask price and written at the market bid price. Therefore it is necessary to compare the model value to the market bid and ask prices instead of the mid-market price, because comparison with the mid-market price might provide wrong signals to buy or write an option. To illustrate, let the market bid price be DFl 3 and offer price be DFl 5. The mid-market price is therefore DFl 4. If the model value is DFl 3.5, the mid-market price is greater than the model value. This indicates that the option is over-priced in the market and therefore should be written. However, the option can only be written at the bid price of DFl 3, which is less than the model value, indicating that the option is actually under-priced in the market and should be bought. Hence the signal generated by comparison of the model value with the mid-market price is not correct.

To overcome this difficulty, mispriced options are identified by comparing the model value to the market bid and ask prices as follows :

1) if the bid price is greater than the model value, the option is over-priced and can be written at the bid price;

2) if the ask price is less than the model value, the option is under-priced and can be bought at the ask price;
3) if the bid price is less than or equal to the model value or the ask price is greater than or equal to the model value, the option is not mis-priced.

When bid and ask prices are used, the criterion for determining whether the initial mispricing has reversed follows from the rule used for determining mis-priced options in the presence of bid and ask prices. That is, for an initially over-priced option (model price is less than the bid price), this mis-pricing is reversed when the ask price is less than or equal to the model price. Similarly, for an initially under-priced option (model price is greater than the ask price), the mis-pricing is reversed when the bid price is greater than or equal to the model price.

4.6 Riskless Strategies

If the model used is assumed to be correct, then when an option is mis-priced, we expect the market price to return to the model value some time in the future. Therefore this deviation of the market price from the model value represents a potential profit. The strategy is to buy (write) the under-valued (over-valued) option to lock in the potential profit without incurring any risk. A position is riskless in the sense that its return is insensitive to small changes in the price of the underlying stock over a short period of time. This would be the case if the model used is correct and the position is continuously hedged, so that the deviation of the market price from the model price is a certain profit and the risk-free rate of return on the investment in the position is also certain. It is necessary to set up a riskless position because if the position is risky then the rate of return from that position must be above a risk-adjusted rate of return to be considered abnormal. But what is the appropriate risk-adjusted rate of return is not clear. Jarrow and Rudd (1983) showed that the option's beta is equal to the option's elasticity times the stock's beta, that is $\beta_c = n\beta_s$, where β_c is the option's beta,

β_s is the underlying stock's beta,

n is the option's elasticity and is equal to $\delta C/\delta S(S/C)$ and

$\delta C/\delta S$ is the first partial derivative of the Black-Scholes call price with respect to the underlying stock price.

S and C are defined in Appendix 1. For the Black-Scholes formula, $\delta C/\delta S$ is equal to $N(d_1)$ (see Appendix 1 for definition).

As the option's elasticity is a function of the stock price and time, it follows that the option's beta changes over the life of the option even if the stock's beta remains constant. Therefore, unlike stocks, the option's beta, which is non-constant, cannot be estimated from the past time-series of returns on the option and the returns on the market portfolio, and hence the Capital Assets Pricing Model, commonly used in empirical studies of stock market efficiency, cannot be used to determine the expected return. In the case of a riskless position, the expected rate of return is obvious : it is the riskless rate of return.

An example of a study that used a risky strategy and an unadjusted rate of return is Trippi(1977). Trippi investigated the efficiency of the Chicago Board Options Exchange. His trading strategy involved buying options that were under-valued and writing options that were over-valued. The positions were not hedged and therefore not riskless. Based on an average weekly return of 11.4 per cent he concluded that the Chicago Board Options Exchange was inefficient during the period studied. However, it is difficult to evaluate Trippi's result fully : he conducted _ex post_ test, and his strategy was not riskless, and the reported return was not risk-adjusted.

Hedging, spreading and conversion strategies have been used to create riskless positions. A hedge "combines an option with its underlying stock in such a way that either the stock protects the option against loss or the option protects the stock against loss" (Cox and Rubinstein(1985) p.8). To implement a hedge, orders have to be placed in two markets : the stock and the options market. This usually takes a longer time than executing the orders in one market. As long as one leg of the hedge is not executed, the position is not hedged, and the longer the time between the execution of both legs of the hedge, the higher the risk.

Black and Scholes(1972) avoided the need to determine a risk-adjusted return by establishing a riskless hedge position consisting of buying (selling) an option and selling (buying) a certain proportion of the underlying stock. This proportion is known as the hedge ratio and is given by the first partial derivative of the Black-Scholes call price with respect to the stock price. This has been shown to be equal to $N(d_1)$. (Black and Scholes(1973)). Alternatively, the riskless position can be achieved by buying (selling) 100 shares of the underlying stock and writing (buying) $1/N(d_1)$ contracts of the option. For the Black-Scholes model with the Merton dividend adjustment, Chiras and Manaster(1978) showed that the hedge ratio is $e^{-DT}N(d_1)$. (See Appendix 1 for definition of parameters).

"A spread combines options of different series but of the same class, where some are bought and others are written" (Cox and Rubinstein (1985) p.12). The advantage of using a spreading strategy is that both legs of the transaction can be executed in one market, and possibly with one market-maker, since only one class is involved. A riskless position can be established by a spreading strategy involving positions in two options of the same class. To illustrate, suppose there are two options, option j and option k, written on the same stock. Let $e^{-DT}N(d_{1j})$ and $e^{-DT}N(d_{1k})$ be the hedge ratios of options j and k respectively. That is, for every 100 shares of the underlying stock bought (sold), write (buy) $e^{DT}/N(d_{1j})$ contracts of option j to form a riskless hedge. The riskless hedge can also be formed by buying (selling) 100 shares of the underlying stock and writing (buying) $e^{DT}/N(d_{1k})$ of option k. Since the 100 shares are the same in both cases, it provides the link between the two options. A riskless spread can be established by buying (writing) $e^{DT}/N(d_{1j})$ contracts of option j and writing (buying) $e^{DT}/N(d_{1k})$ of option k. Equivalently, the riskless spread can be established by buying (writing) one contract of option j and writing (buying) $N(d_{1j})/N(d_{1k})$ contracts of option k.

Conversion strategy is used to exploit the relative mis-pricing of put and calls. It is essentially one of arbitrage between put and call markets. If a call is found to be over-priced relative to a put, a riskless position is set up using a conversion strategy. This involves writing a call and buying it back immediately by buying a put, buying a share, and borrowing an amount equal to the present value of the exercise price of the option (assuming the stock pays no dividends). Similarly, if a put is over-priced relative to the call, the strategy will be to write a put and buy it back immediately by buying a call, selling the underlying stock short, and lending an amount equal to the present value of the exercise price of the option. The positions established are riskless because the call (put) that is written is immediately bought. Conversion strategies require orders to be placed simultaneously in three markets : option, stock and bond markets. This makes its implementation difficult and it is of higher risk.

Leland(1985) showed that when transactions costs were present, the use of the B-S hedge ratio did not result in a perfect hedge even with continuous hedging. He developed a modified hedge ratio to ensure that hedging is theoretically riskless in the presence of transactions costs. The modified hedge ratio uses a modified standard deviation as input. This modified standard deviation incorporates the transactions costs (including the bid-ask spread) and the rebalancing interval. The actual bid-ask spread may be different from the quoted spread because trades sometimes occur within the quoted spread. The actual bid-ask spread cannot be easily determined and errors in its estimation will translate into errors in the modified hedge ratio. The benefit from using the modified hedge ratio without an accurate estimation of the transactions costs is not clear, and it is therefore not used in this study. The sensitivity of the results to this deviation is a matter for future research.

4.7 Spreading Test

The spreading test in this study sets up spreads that consist of an under-priced series and an over-priced series of the same class. If there are no under-priced series or no over-priced series within that class then no spreads will be set up.

Although spreads that consist of two under-priced or two over-priced series can also be profitable, they are ignored in this study. Such spreads are profitable if the ratios of mis-pricing (model price / actual price) of the two options are different, and the relatively under-priced option is bought and the other option written. These spreads are ignored because this study rebalances spreads daily till they are liquidated. This daily rebalancing might lead to the undesirable situation where over-priced options have to be bought or under-priced options have to be written in order to maintain the hedge ratio. To see how this may come about, consider a riskless spread consisting of two over-priced options A and B and one contract of A is bought and 0.8 contract of B is written (hedge ratio of 1:0.8 assumed). Further assume that the hedge ratio has now changed to 1.5 : 1. To conform to this ratio, the spread can be adjusted by buying another 0.2 contract of option A (which is over-priced) or by buying back 0.13 contract of option B (which is also over-priced). Either alternative requires an over-priced option to be bought. Such action will therefore result in expected losses.

The spread is liquidated when the price of one or both legs of the spread returns to its model value, or the mispricing of at least one leg is reversed or at the end of the sample period.

An option is bought (written) when its market price deviates from its model value so that it is under-priced (over-priced). As pointed out earlier on, this mispricing is a potential profit and the strategy is to 'lock in' this profit. When the market price of the option returns to its model value or when the mispricing is reversed, this potential profit would have been realised. Hence the option position should be liquidated. However, one difficulty is that there are two legs in a spread, and it is highly unlikely that both legs will have their mis-pricing reversed on the same day. It is possible that the mispricing of one leg has widened before it moves toward the model value. This being the case, if the spread is liquidated, there is a possibility that the profit from the leg that has its mis-pricing reversed might be reduced or even turned into a loss by the loss from the leg that is still mis-priced. However, if the spread is not liquidated when the mis-pricing of one leg of the spread has reversed, the spread will have a long (short) position on an option that has become over-priced (under-priced). Moreover, both legs of the spread will now consist of under-priced (over-priced) options. As discussed above, this is undesirable when the spread has to be rebalanced daily because it will become necessary to buy over-priced options or sell under-priced options to maintain a riskless position.

To overcome this problem, when only one leg of the spread has reversed, an attempt will be made to replace the leg whose mis-pricing has reversed with another option, so that the leg whose mis-pricing has not reversed need not be liquidated. This, of course, is not always possible as it depends on the availability of another over-priced (or under-priced) option of the same class to match the currently under-priced (or over-priced) option whose mis-pricing has not reversed. If another option is available, the number of contracts of the new option to be bought (or written) depends on the number of contracts of the existing option and the hedge ratios of both options. This rule allows the leg whose mis-pricing has reversed to be liquidated and the other leg to continue to be held until its mis-pricing has reversed. It is consistent with Cox and Rubinstein(1985)'s suggestion that "whenever one side of a neutral position becomes unfavourable, liquidate that side and replace it with another option with a favourable price" (p.185).

4.8 Calculation of the Rate of Return from a Spread

When a spread is liquidated, its rate of return is computed. Computation of the rate of return is problematical when option writing is involved. Gastineau(1975) noted that "although the dollar profit is simple enough to compute if the price at which a transaction will be closed out is given, the amount of capital invested (the denominator in the rate of return calculation) is not easy to determine" (p.223). In option writing, the writer receives the option premium. However, he is required to furnish a margin (see Chapter Two Section 2.4) to ensure that he is able to fulfil his obligations under the contract. The option premium reduces the margin required. This net margin can be satisfied by depositing cash or securities.

Chiras and Manaster(1978) used the gross investment (the sum of the values of the long and short positions) as the denominator in their rate of return calculations. Their justification for doing this was that many of the rates of return in their sample were infinite when the net investment (the value of the long position less the short position) was used, because the net investment was negative. However, it is clear that the capital 'tied-up' in the spread is not equal to the gross investment. Hence, using the gross investment cannot be correct.

Gastineau(1975) suggested that the net margin be included in the denominator but at the same time the return from the securities furnished as margin be included in the numerator. If it is assumed that the securities to be deposited to satisfy the margin requirements are not already in the investment portfolio of the trader, and these securities have to be purchased, then Gastineau's suggestion would seem to be correct, as the options could not have been written without the securities being purchased. Hence, the options written and the securities purchased are viewed as one investment portfolio, and it is the return on this portfolio that is of interest.

However, in the context of this study, there is a difficulty in using Gastineau's method because two assumptions are necessary : one regarding the type of securities purchased and deposited and the other regarding the return from that security. These assumptions complicate the rate of return calculations.

In order to overcome this difficulty, it is assumed that the trader already possesses, in his portfolio, the securities needed to satisfy the net margin requirement. With this assumption, the net margin can be ignored, since the securities deposited to satisfy this requirement are already invested, and the net margin requirement makes no difference to the trader's return. Hence, the net margin is ignored and the investment in the spread is equal to the amount required to set up the buy leg of the spread.

The annualised rate of return from the spread is computed as follows :

$$\frac{\text{Total profit (or loss) for the spread}}{\text{Investment in the spread}} \times \frac{250}{\text{Holding Period}}$$

where the holding period is measured from the time the spread is set up, to the time it is liquidated. Two hundred and fifty days is used to annualise the rate of return since it is the approximate number of trading days in a year. It is assumed that whatever return is earned during the period in which the spread is held, it can only be replicated during trading days. To be consistent, the holding period is also measured in trading days.

4.9 Rebalancing of Spreads

For the duration that the spread is held, the spread ratio (that is $N(d_{1j})/N(d_{1k})$ for two options j and k, where j is bought and k is sold) is re-calculated each day and the proportions of options in the spread are adjusted accordingly. This adjustment is achieved by buying more of the under-valued option or selling more of the over-valued option. If the spread ratio (that is $N(d_{1j}) / N(d_{1k})$) at day t+1 is greater than the spread ratio at day t, then at day t+1 the spread is adjusted by writing more of the over-valued option (k). If the spread ratio at day t+1 is less than the spread ratio at day t, then at day t+1 the spread is adjusted by buying more of the under-valued option (j). In the *ex ante* test, the adjustments that are determined on day t can only be executed on day t+1. In the tests with transactions costs, options are bought and written at the bid and ask prices respectively during rebalancing.

Rebalancing the spreads daily deviates from the Black-Scholes assumption of continuous rebalancing and the spread will not, therefore, be completely riskless. However, Galai(1975) argued that "the fact that the adjustment in the position is not done continuously, but daily (or even over longer periods) should not significantly affect, on average, the returns on the spread" (p.140). He showed that the spreading return can be decomposed into the weighted difference between the hedging returns from the two options in the spread, and that the effect of discreteness of adjustment for one hedge will to some extent offset the effect for the other hedge. This offsetting is due to the fact that the effects in both cases are a function of the reduction in time to maturity and the change in price of the underlying stock. These two factors are the same for both options since they are written on the same underlying stock. The spreading return will in fact be dominated by the weighted difference between the changes in the deviation of the actual price from the model price for each option.

4.10 Hedging Tests

The hedging test in this study sets up hedges consisting of one contract of an option and $100e^{-DT}N(d_1)$ shares of its underlying stock, where $e^{-DT}N(d_1)$ is the hedge ratio (see Appendix 1 for definition of the parameters). If the option is under-priced, it is bought and the underlying stock sold short; if the option is over-priced, it is written and the underlying stock bought.

The hedge is liquidated when the market price of the option returns to its model value, or when the mis-pricing of the option is reversed, or at the end of the sample period.

The underlying assumption for the hedging test is that the Amsterdam stock market is informationally efficient, so that stocks are fairly priced. Some evidence of the efficiency of the Amsterdam stock market is provided by Solnik(1973) and by Dorsman and Gooijer(1981). Solnik found some evidence in support of the random walk hypothesis, and showed that any deviations from the random walk hypothesis were not sufficient to generate abnormal returns after transactions costs. Dorsman and Gooijer(1981) also studied the behaviour of Dutch stock prices and concluded that "the Amsterdam Stock Exchange can be considered to operate in a perfectly efficient way" (p.30) during the period of their study.

4.11 Calculation of the Rate of Return from a Hedge

A formula similar to that for the annualised rate of return from a spread is used to compute the annualised rate of return from a hedge. The formula is :

$$\frac{\text{Total profit (loss) from a hedge}}{\text{Investment in the hedge}} \times \frac{250}{\text{Holding period}}$$

The investment in the hedge is the amount required to set up the long side of the hedge. In the case where the option is bought and the stock is sold short, it is likely that the proceeds from the sale of the stock are not immediately available to the trader. Hence, the investment in the hedge is equal to the amount required to buy the option. Similarly, when the stock is bought and the option is written, the proceeds from option writing are not immediately available to the trader; in fact, a net margin has to be furnished in the form of securities. As discussed in Section 4.8, this net margin is to be ignored in this study. Therefore, the investment in the hedge is equal to the amount required to buy the stock.

4.12 Rebalancing of Hedges

For the duration that the hedge is held, the hedge ratio (that is, $e^{-DT}N(d_1)$) is re-calculated each day and the proportions of option and stock in the hedge are adjusted accordingly.

Consider the case where the option is bought and the stock is sold short. If the hedge ratio on day t+1 is greater than the hedge ratio on day t, then on day t+1 the hedge is adjusted by selling more of the stock; if the hedge ratio on day t+1 is less than the hedge ratio on day t, then on day t+1 the hedge is adjusted by buying more of the option.

Next consider the case where the stock is bought and the option is written. If the hedge ratio on day t+1 is greater than the hedge ratio on day t, then on day t+1 the hedge is adjusted by buying more of the stock; if the hedge ratio on day t+1 is less than the hedge ratio on day t, then on day t+1 the hedge is adjusted by writing more of the option.

Rebalancing the hedges daily deviates from the Black-Scholes assumption of continuous rebalancing and the hedge will, therefore, not be completely riskless. Boyle and Emmanuel(1980) had shown that discretely adjusted Black-Scholes hedge constructed with model prices will have excess returns with zero means and positive skewness, resulting in about sixty eight per cent of all hedge excess returns being negative. However, if the discretely adjusted hedges are established at market prices, the hedge excess returns need not have these distributional characteristics. Galai(1983a) showed that the hedging return can be decomposed into three components :

a) the riskless rate of return on the initial investment in the hedge,
b) the return from the discreteness of adjustment of the hedge and
c) the return from the change in the deviation of the actual option price from the model price over the period the hedge is held.

He provided evidence that the effect of discreteness of adjustment (component (b)) was negligible and that component (c) dominated the hedge return. Thus, he concluded that "adjustments at one (trading) day intervals apparently do not affect the returns in a significant way and can thus be regarded as operational for hedging activity" (p.52).

4.13 Premature Exercise of Options

Even though an American option can be exercised prematurely, Merton(1973a) had shown that early exercise is never optimal when the underlying stock does not pay dividends. However, for an American option on a dividend-paying stock, there is the possibility that it is optimal to exercise the option prematurely. As all stock options traded on the European Options Exchange are American options, this possibility cannot be ignored, because options that are bought or written and assumed to be held till the mis-pricing is reversed or till the end of the sample period, might in fact be exercised in the interim.

Jarrow and Rudd(1983) considered the case where over the life of the option the underlying stock pays two dividends D_1 and D_2 at times T_1 and T_2 respectively. The option matures at time T ($T > T_2 > T_1$) and X is the exercise price. They showed that if

$$X(1 - e^{-r(T-T_1)}) > D_1$$

and

$$X(1 - e^{-r(T-T_2)}) > D_2$$

then the American option will never be exercised early. Violation of either of the conditions will mean that the probability of early exercise may no longer be zero. However, there is no unambiguous criterion to determine whether the option will be exercised early. In order to overcome this uncertainty, all in-the-money options on stocks that are expected to pay dividends during the period of study are ignored for trading purposes if they violate any of the above conditions.

4.14 Tests of Significance

The t-test is used to test the significance of the difference between the average annualised rates of return from spreading (and from hedging) and an estimated risk-free interest rate.

In this study, the conventional five per cent significance level is used. This choice must be arbitrary as Henkel(1976) stated that "the choice of significance level at which to work is an arbitrary decision, since neither substantive theory nor statistical theory dictate a particular level of significance be used" (p.77).

The objective of this study is to determine the efficiency of the European Options Exchange. Given the definition of efficiency in this study, it would only be of interest to know whether the average rate of return is significantly greater than the estimated risk-free interest rate. It makes no difference to the conclusion whether the average rate of return is less than or equal to the estimated riskless interest rate. Hence, a one-tail test is appropriate. The null hypothesis is : H_0 : u = r and the alternative hypothesis is H_1 : u > r where u is the average rate of return and r is the estimated risk-free interest rate.

To use the t-test, the average rates of return have to be normally distributed. Since the sample sizes are large in most cases, we can be sure, by virtue of the central limit theorem, that the average rates of return are normally distributed (Hoel(1971)).

4.15 Summary

This chapter reviewed the methodological issues and described the methodology used in this study.

One major issue that needed to be resolved was the choice of the estimator for the standard deviation of the underlying stock's return. Black and Scholes(1972) had stressed the importance of using an accurate estimation of the standard deviation of the underlying stock's return in their model. The standard deviation of the underlying stock's return is difficult to estimate. A particular estimator might produce inaccurate estimates so that the conclusion of the tests may be sensitive to a change of the estimator in the trading rule. Hence, if there is no reason for rejecting a particular estimator, then it is necessary to include that estimator in the tests.

Three estimators (items (b), (i) and (m)) out of the list of thirteen (see Section 4.2) will be tested in this study. The other estimators are rejected because

1) they have no theoretical foundation (items (d), (g), (h), (j) and (k)) or
2) the available empirical evidence showed that they are inferior to one of the three estimators that will be tested in this study (items (a), (c) and (e)) or
3) the estimates cannot be observed and there are too few observations available to get reliable estimates (item (f)) or
4) the exact prediction rule is not known and the judgement of an individual is sometimes important in obtaining the estimates (item (l)) or
5) the data required is not available (transactions data implied standard deviation).

The issue of what to include in the denominator (that is, the size of the investment in the hedge or spread) when calculating the rate of return from hedging or spreading was also discussed. It was argued that the investment in the spread or hedge should be equal to the amount required to set up the buy leg of the spread or hedge.

Four types of tests will be conducted in this study : the *ex post* test, the *ex ante* test, the *ex ante* test with the bid-ask spread cost and the *ex post* test with the bid-ask spread cost. Two riskless strategies, spreading and hedging, will be tested and daily rebalancing of spreads and hedges will be carried out to maintain the positions riskless. Also, in order to avoid problems caused by the premature exercise of options, all in-the-money options with non-zero probability of early exercise are ignored for trading purposes.

References

Beckers, S. "Standard Deviations Implied in Option Prices as Predictors of Future Stock Price Variability", **Journal of Banking and Finance**, 1981 pp363-381

Bhattacharya, M. "Transactions Data Test of Efficiency of Chicago Board Options Exchange", **Journal of Financial Economics**, 1983 pp161-185

Black, F. "Fact and Fantasy in the Use of Options", **Financial Analysts Journal**, July-August 1975 pp36-72

Black, F. and Scholes, M. "The Valuation of Option Contracts and a Test of Market Efficiency", **Journal of Finance**, 1972 pp399-417

Black, F. and Scholes, M. "The Pricing of Options and Corporate Liabilities", **Journal of Political Economy**, 1973 pp637-659

Blomeyer, E. C. and Klemkosky, R. C. "Tests of Market Efficiency for American Call Options", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath and Co., Lexington Books, 1983

Boyle, P. P. and Emanuel, D. "Discretely Adjusted Option Hedges", **Journal of Financial Economics**, 1980 pp259-282

Brenner, M. and Galai, D. "On Measuring the Risk of Common Stocks Implied by Options Prices : A Note", **Journal of Financial and Quantitative Analysis**, December 1984 pp403-412

Brenner, M. and Subrahmanyam, M. G. "A Simple Formula to Compute the Implied Standard Deviation", **Financial Analysts Journal**, September-October 1988 pp80-83

Chiras, D. and Manaster, S. "The Information Content of Option Prices and a Test of Market Efficiency", **Journal of Financial Economics**, 1978 pp213-234

Choi, J., Salandro, D. and Shastri, K. "On the Estimation of Bid-Ask Spreads : Theory and Evidence", **Journal of Financial and Quantitative Analysis**, 1988 pp219-230

Cox, J. and Rubinstein, M. "**Options Markets**", Prentice Hall, Inc., 1985

DATASTREAM **Traded Options Services Users' Manual**

Dorsman, A. B. and de Gooijer, J. G. **"On the Behaviour of Dutch Stock Market Prices and The Random Walk Hypothesis"**, Paper presented to the International Symposium on Forecasting, Quebec City, Canada, May 1981

Galai, D. **"Pricing of Options and the Efficiency of the Chicago Board Options Exchange"**, Unpublished Ph.D. dissertation, University of Chicago, 1975

Galai, D. "Tests of Market Efficiency of the Chicago Board Options Exchange", **Journal of Business**, 1977 pp167-197

Galai, D. "The Components of the Return from Hedging Options against Stocks", **Journal of Business**, 1983a pp45-54

Galai, D. "A Survey of Empirical Tests of Option Pricing Models", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath & Co., Lexington Books, 1983b

Gastineau, G. **"The Stock Options Manual"**, McGraw-Hill Book Co 1975

Gemmill, G. "The Forecasting Performance of Stock Options on the London Traded Options Market", **Journal of Business Finance and Accounting**, Winter 1986 pp535-546

Gemmill, G. and Dickins, P. "An Examination of the Efficiency of the London Traded Options Market", **Applied Economics**, 1986 pp995-1010

Henkel, R. E. "**Tests of Significance**", Sage Publications, Inc., 1976

Hoel, P. G. "**Introduction to Mathematical Statistics**", John Wiley & Sons, Inc., 1971

Jarrow, R. and Rudd, A. "**Option Pricing**", Richard D. Irwin Inc, 1983

Jensen, M. C. "Some Anomalous Evidence regarding Market Efficiency", **Journal of Financial Economics**, 1978 pp95-101

Kemna, A. "An Empirical Test of the Option Pricing Model Based on Transactions Data of the European Options Exchange", Paper presented to the **European Finance Association Meeting**, 1987

Kerruish, A. "An Empirical Test of the Black-Scholes Option Pricing Model in the UK and Implications for Market Efficiency", Presented to the **European Finance Association Meeting**, September 1985

Latane, H. A. and Rendleman, R. J. "Standard Deviations of Stock Price Ratios Implied in Option Prices", **Journal of Finance**, 1976 pp369-381

Latane, H. A. and Rendleman, R. J. "Correction to 'Standard Deviation of Stock Price Ratios Implied in Option Prices', May 1976", **Journal of Finance**, 1979 pp1083

Leland, H. "Option Pricing and Replication with Transactions Costs", **Journal of Finance**, 1985 pp1283-1301

Macbeth, J. D. and Merville, L. J. "An Empirical Examination of the Black-Scholes Call Option Pricing Model", **Journal of Finance**, 1979 pp1173-1186

Merton, R. C. "Theory of Rational Option Pricing", **Bell Journal of Economics and Management Science**, 1973a pp141-183

Merton, R. C. "The Impact on Option Pricing of Specification Error in the Underlying Stock Price Returns", **Journal of Finance**, 1976 pp333-350

Phillips, S. and Smith, C. "Trading Costs for Listed Options: The Implications for Market Efficiency", **Journal of Financial Economics**, 1980 pp179-201

Roll, R. "A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market", **Journal of Finance**, 1984 pp1127-39

Schmalensee, R. and Trippi, R. R. "Common Stock Volatility Expectations Implied by Option Premia", **Journal of Finance**, March 1978 pp129-147

Solnik, B. H. "Note on the Validity of the Random Walk for European Stock Prices", **Journal of Finance**, December 1973 pp1151-59

Trippi, R. "A Test of Option Market Efficiency Using a Random Walk Valuation Model", **Journal of Economics and Business**, 1977 pp93-98

CHAPTER FIVE

DATA

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Data

5.1 Introduction

This chapter describes how the data for this study are obtained from DATASTREAM. The DATASTREAM option pricing model is described, followed by a discussion of the advantages and disadvantages of obtaining data from this source. It also describes the calculation of the model values, hedge ratios, time to maturity, and states the reasons for the exclusion of certain options. It elaborates on DATASTREAM's method of imputing the implied standard deviation of the underlying stock's return from each option, and shows how this implied standard deviation is combined with a historical measure to estimate the stock's volatility.

5.2 DATASTREAM's Option Pricing Model

The data for this study are downloaded from DATASTREAM each trading day after the close of the market at 4.30pm (Amsterdam time).

The DATASTREAM traded options service uses the Black-Scholes model with the Merton dividend adjustment to derive model values. The model is described in Appendix 1.

For options written on dividend-paying stocks, there is a non-zero probability of early exercise, so that the American call is worth more than the European call. Since the Black-Scholes model with the Merton dividend adjustment provides the value for an European call, this undervaluation needs to be corrected. DATASTREAM computes the European model values with expiry dates corresponding to the ex-dividend dates as well as the contract expiry date. The maximum of these is taken as the model value. This method is commonly referred to as the Pseudo-American method.

5.3 Advantages and Disadvantages of Obtaining Data from DATASTREAM

The advantage of obtaining the data from DATASTREAM is that DATASTREAM receives online price quotations from the EOE. The use of price quotations eliminates the selection bias problem identified by Phillips and Smith(1980). This problem arises when transactions prices are used to pick out say, under-priced, options and an ex post test is employed. Phillips and Smith argued that a rule that uses transactions prices "will systematically pick out, as undervalued, call prices from transactions initiated by orders to sell" (p.186). This is because options are assumed to be sold at the bid price, which is at the lower end of the bid-ask spread and hence is more likely to be picked out as under-valued when it is compared to model prices. But the trading rule will, in this case, assume that these under-valued options are bought at the bid price since this the transaction price. In the zero transactions costs case, options should be bought at the mid-market price instead of the bid price. Thus, this trading rule resulted in a selection bias equal, on average, to approximately half the bid-ask spread.

Using bid and ask quotations also permits the bid-ask spread cost to be taken into account explicitly. If transaction prices are used, an estimated bid-ask spread has to be used.

In addition, since the data are downloaded each trading day after the close of the market, the option and stock prices downloaded are quotations from the market-makers and the 'hoekman' at the close of both markets at 4.30pm (Amsterdam time). Thus there is no non-simultaneity problem with respect to these prices. The problem of possible non-simultaneity of closing stock and option transactions prices was noted as early as 1975 by Galai(1975). He stated that "closing prices do not always reflect a synchronisation of the transactions on the CBOE and the NYSE" (p.20). Bookstaber(1981) clearly illustrated this problem. The consequence of non-simultaneity in the closing prices is that any observed mis-pricing of the option may be illusory (see Chapter One Section 1.5). The option prices downloaded from DATASTREAM are the highest bid and lowest ask quotations from the traders on the European Options Exchange. The stock prices are quotations from the 'hoekman' on the Amsterdam Stock Exchange. Literally, the word 'hoekman' means 'corner-man'. In the old days, someone would stand in a 'hoek', or corner, of the exchange and quote buy and sell prices when asked. Nowadays, the 'hoekman' makes market and trade for his own account but he does not deal with the public. He specialises in certain stocks and bonds. For each stock there is more than one 'hoekman' so that "the result is that, at any given moment, there's a single price quotation agreed on by the competing specialists, rather than bid and offer prices" (Adam and Peagam(1985) p.16).

Although there are advantages in using online price quotations, there are disadvantages too. One disadvantage is that market makers are only obliged, under European Options Exchange Trading Rules (see Chapter Two Section 2.3), to buy (sell) five contracts at the quoted bid (ask) price. Beyond five contracts, the prices quoted need not necessarily apply. Another disadvantage is that it is very time consuming to download the data. The data had to be downloaded each and every trading day. It is unlike archival data, where months and even years of data can be downloaded in a day. Also, the data for any day can be 'lost' if it is not collected within the day. This can happen when there are technical problems either at Glasgow University Computer Centre, at DATASTREAM, or at the European Options Exchange. When this happens, it creates a gap in the data sample so that the trading strategy cannot be properly tested; options cannot be bought or sold on that day since prices are not downloaded. To eliminate this gap in the data, data collection has to be restarted from the following day. Thus, the actual time required to collect say, one months' data, is usually much longer than one month.

5.4 Downloading and 'Cleaning' the Data

The main part of the data is downloaded using two of DATASTREAM's programs : 201C and 201F. The name of the underlying stock, stock price, maturity date, exercise price, bid price, ask price and implied standard deviation of the underlying stock's return are downloaded using program 201F; the model price, the hedge ratio and the dividends forecasts are downloaded using program 201C.

The problem with downloading data in this manner is that the data are downloaded together with other unwanted data in the formats shown in figure 5-1 (for 201C) and figure 5-2 (for 201F). These formats are screen images that are generated by the programs. These data, therefore, had to be 'cleaned up'; that is, the relevant data had to be extracted from these formats and arranged in a form suitable for further processing.

5.5 Calculation of Model Values and Hedge Ratios

The model price and hedge ratio downloaded from DATASTREAM are calculated using DATASTREAM's estimator of the standard deviation of the underlying stock's return. As two other estimators of the standard deviation are to be tested in this study, model prices and hedge ratios have to be re-calculated with each of these estimators as input. In order to program the calculations of these model prices and hedge ratios, an approximation to the cumulative standard normal distribution function is used. This study uses the following approximate integral from Stuart and Ord(1987) (p.502) :

$$\int_{-x}^{x} \frac{1}{(\sqrt{2\pi})} e^{-0.5t} \, dt \leq \sqrt{(1 - e^{(-2x^2/\pi)})}$$

By taking the equality, the error has been shown to be less than 0.75 per cent.

5.6 Calculation of the Time to Maturity

To facilitate the calculation of the time to maturity, the maturity dates, ex dividend dates and current date are expressed as Julian dates, that is, the dates are expressed as day 1 for 1 January 1988, day 2 for 2 January 1988, day 366 for 31 December 1988, day 367 for 1 January 1989 and so on. With this expression, the time to maturity (expressed as a proportion of a year) is simply the difference between the maturity date (or the ex dividend date) and the current date divided by 366. The Julian dates are obtained from a date conversion table in Cleeton(1979). The table is shown in figure 5-3.

5.7 DATASTREAM's Estimator of the Standard Deviation of a Stock's Return

DATASTREAM estimated the standard deviation of a stock in the following way :

"(a) an historical measure of volatility (standard deviation of logged prices) is calculated for each maturity using the same duration of past observation as the period to be forecast, i.e. 6 months daily prices for a 6 months expiry date.

(b) the market implied volatility for each expiry is determined by calculating implied volatility for each series in the expiry month and weighting by the last 5 days' trading activity.

(c) the final volatility forecast is an average of the previous two estimates.

The result is a per expiry volatility forecast which reflects not just an historical perspective, but incorporates the market's anticipation of future volatility. The volatilities are always expressed on an annual basis and are recalculated weekly." (DATASTREAM Traded Options Services User Manual p.34).

The market implied volatility is the volatility currently accorded to the stock by the market. It is obtained by equating the model price of the option to its market price. However, there are two market prices, the bid price and the ask price. DATASTREAM equates the model price to the mid-market price, that is, the average of the bid and ask prices (confirmed through telephone conservation with DATASTREAM staff). Kerruish(1984) referred to this as the 'MID' method. It is also possible to impute two implied standard deviations for each series by equating the model value to the bid and to the ask market prices. Kerruish referred to this as the 'B+O' method. In her test, she found it "very difficult to discern which of the bid-offer spread adaptions is more suitable, (B+O or MID), although casual observation suggests the MID model" (p.30). Furthermore, she concluded that "an adjustment was needed to account for the bid-ask spread; with the 'MID' adjustment model recommended" (p.40). In view of this, DATASTREAM's implied standard deviation will be used and no attempts will be made to re-calculate the implied standard deviations using the 'B+O' method.

DATASTREAM uses the Pseudo-American Black-Scholes model to compute the model values of options. This results in a slight complication because with the Pseudo-American model, there may be a few model values, depending on the number of dividends that will be paid during the option's remaining life. Each of these model values will generate an implied standard deviation when equated to the market price. Which of these implied standard deviations should be chosen?

The Pseudo-American method selects the largest of all possible model values as the model value. The problem is that the standard deviation of the stock's return is not known and therefore we would not know which of the possible model values is largest. However, it can be shown that the largest model value is the one that generates the smallest implied standard deviation, and hence the implied standard deviation consistent with the Pseudo-American method is the smallest of all the implied standard deviations generated . To see why this is so, assume that there is only one dividend payment throughout the life of the option. Hence two ISDs will be calculated :

1) The option is assumed to be held to maturity so that

   $ISD1 = f(C^*, Se^{-DT}, r, X, T)$ where C^* is the actual market price of the option.

2) The option is assumed to be exercised on the day before the ex-dividend day so that

   $ISD2 = f(C^*, S, r, X, T_1)$ where T_1 is the time period from the current day to the day before the ex-dividend day.

If ISD1 < ISD2 then

$$C(ISD2, Se^{-DT}, r, X, T) > C(ISD1, Se^{-DT}, r, X, T) = C^*.$$

Hence ISD2 cannot be the 'true' ISD if the standard deviation is to be stationary over the entire period T.

If ISD2 < ISD1 then

$$C(ISD1, S, r, X, T_1) > C(ISD2, S, r, X, T_1) = C^*.$$

Hence ISD1 cannot be the 'true' ISD.

Thus the appropriate ISD is the smallest of the ISD values obtained by equating the market price of the call to each of the Pseudo-American values. This proof is adapted from Beckers(1981).

5.8 Risk-free Rate of Interest

The estimate of the risk-free interest rate used is the Eurocurrency rates of the Netherland guilder in the London money market. Borrowing and lending rates for short maturity (i.e. two days), seven days, one month, three months, six months and one year maturities are available from DATASTREAM program 28V. A sample of the output is shown in figure 5-4. These interest rates do not vary very substantially during each of the periods under study. In the first sample period (16 August 1988 to 27 September 1988), the lowest mid-market rate for the seven-day maturity is 5 percent and the highest mid-market rate for the one-year maturity is 6.031 percent. The average mid-market rate for the three-month maturity is 5.534 percent. Thus the maximum error that can result from using the average mid-market rate for the three-month maturity is about 0.5 percent. In the second sample period (4 November 1988 to 15 December 1988), the lowest mid-market rate for the seven-day maturity is 5.063 per cent and the highest mid-market rate for the one-year maturity is 5.813 per cent. The average mid-market rate for the three-month maturity is 5.377 per cent. Thus, the maximum error that can result from using the average mid-market rate of the three-month maturity is less than 0.5 per cent. Therefore, in each sample period, the average of the mid-market rate for three-month maturity during the period is used. This average rate can be expected to be higher than the risk-free interest rate as it is the average of commercial borrowing and lending rates . However, the results are not expected to be sensitive to this approximation. Galai (1977) had shown that the use of various estimates of the risk-free interest rate, such as 8 per cent and 10 per cent as approximations to the average Treasury bills rates and commercial paper rates respectively, made no qualitative difference to his results. He concluded that "the results are robust to changes in parameters" (including the risk-free interest rate) (p.195). Also, Black(1975) noted that "a one percentage point change in the interest rate does not generally have much effect on the value of an option" (p.41).

5.9 Sample Periods

This study covers two separate time periods :

1. 16 August 1988 - 27 September 1988
2. 4 November 1988 - 15 December 1988

These time periods are chosen arbitrarily. Two different time periods are used in order to determine whether any efficiency (or inefficiency) is to some extent persistent over time. Keane(1983) argued that to have operational significance an inefficiency must be exploitable and to be exploitable it should satisfy four criteria. One of these criteria is persistence, on the basis that "it is not sufficient that an inefficiency be shown to have existed in the past, if there are no grounds for believing that it will continue to exist in the future. Hence, even when a material inefficiency has been identified and authenticated, one must be reasonably satisfied that the market will not learn from the experience" (p.24-25). Of course, it can never be known with certainty whether the market will be efficient or inefficient in the future. However, by testing two different time periods, it is hoped that the validity of the findings will be somewhat enhanced if any efficiency or inefficiency is found to be persistent over both periods. Finding that the market is efficient or inefficient in both periods makes it possible to believe with a greater degree of confidence that the market is likely to continue to be efficient or inefficient in the future than if only one period is tested, or if the efficiency or inefficiency does not persist over both periods. If it is found that the market is inefficient in one sample period, but not the other, then it is difficult to say with much confidence whether the inefficiency will continue to exist in the future. Furthermore, it might be argued that with the available evidence the inefficiency observed is not exploitable since it did not satisfy the criterion of persistence. In addition, if the market is inefficient in some time periods only, the inefficiencies are not exploitable if there is no way of knowing in advance in which time periods the market will be inefficient and in which it will be efficient.

In both sample periods, the data consists of options written on nineteen stocks. In the second sample period there are options written on twenty one stocks, but data on options written on two stocks, Van Ommeren Ceteco and Wessanen, are ignored since data on these stocks are not available in the first sample period. It would therefore not be possible to test for persistence of efficiency or inefficiency over two sample periods even if data on these stocks are collected in the second sample period. A list of all the stocks and stock codes is given in Table 5-1 .

5.10 Exclusion of Certain Options

Options with bid prices equal to zero are meaningless, and not traded since they have to be 'sold' to market-makers free. Options with model prices less than DFl 0.1 will be over-priced if compared to options with bid prices of greater than DFl 0.1. However, as ask prices cannot fall below DFl 0.1, if these options are written, they can only be bought at DFl 0.1 or more, guaranteeing a loss. Both of these classes of options are eliminated from the study, together with options that are in-the-money and do not satisfy the Jarrow and Rudd(1983) conditions for no early exercise.

Also, options with hedge ratios equal to zero at any time during the spread or hedge holding period are eliminated. In this study spreads are set up by buying one contract of the under-priced option j and writing $N(d_{1j})/N(d_{1k})$ of the over-priced option k, where $N(d_{1j})$ and $N(d_{1k})$ are the hedge ratios of the options j and k respectively. Thus, it is obvious that a hedge ratio of zero is problematical because it requires either zero or an infinite number of contracts of the over-priced option to be written. A similar problem arises in the case of hedging. Thus, options with hedge ratios equal to zero at any time during the hedge or spread holding period must be eliminated.

In addition, options with three, four and five years maturity are also excluded from this study since it is difficult to obtain an accurate forecast of the stock's volatility over such a long period.

1.	ABN	Algemene Bank Nederland
2.	AEGN	AEGON
3.	AH	Albert Heijn
4.	AKZO	AKZO
5.	AMEV	AMEV
6.	AMRO	Amsterdam Rotterdam Bank
7.	BUHR	Buhrmann-Tetterode
8.	ELS	Elsevier
9.	GB	Gist Brocades
10.	HB	Heineken
11.	HO	Hoogovens
12.	KLM	Koninklijke Luchtvaart Mij
13.	KNP	Koninklijke Nedlloyd Paperfebriek
14.	NED	Nedlloyd Groep
15.	NN	Nationale Nederlanden
16.	PHIL	Philips
17.	RBC	Robeco
18.	RD	Koninklijke Olie (Royal Dutch Petroleum)
19.	UNIL	Unilever

Table 5-1 : List of Stocks and Stock Codes

E.O.E. CALLS OPTION	MARKET PRICE	MODEL PRICE	% CHEAP(-) OR DEAR(+)	GEARING RATIO	HEDGE RATIO
		AMRO BANK LATEST PRICE: FL75.70			
JAN 55	21.20	21.28	-0.3	3.6	1.000
JAN 60	16.20	16.34	-0.9	4.7	1.000
JAN 65	11.20	11.42	-1.9	6.7	1.000
JAN 70	7.00	6.78	+3.3	9.6	0.948
JAN 75	3.30	3.11	+12.6	12.4	0.595
JAN 80	1.35	1.02	+27.3	17.1	0.318
JAN 85	0.55	0.24	+128.2	12.4	0.151
JAN 90	0.50	0.04		4.7	0.080
APR 60	17.20	17.39	-1.0	4.3	1.000
APR 65	12.00	12.83	-6.4	5.9	1.000
APR 70	8.50	8.78	-3.1	7.1	0.921
APR 75	5.10	5.51	-9.2	8.8	0.642
APR 80	2.85	3.17	-11.7	12.0	0.433
APR 85	1.50	1.65	-15.1	15.0	0.261
APR 90	1.05	0.79	+32.7	11.3	0.182

Figure 5-1 : Sample Output from DATASTREAM Program 201C

CALLS

AMRO BANK

LATEST PRICE: FL75.70

OPTION	MARKET BID	QUOTES OFFER	IMPLIED VOL. (ANNUALISED)	FORECAST VOL. (ANNUALISED)	GEARING RATIO
JAN 55	20.70	21.70	0.001	0.188	3.57
JAN 60	15.70	16.70	0.001	0.188	4.67
JAN 65	10.70	11.70	0.001	0.188	6.66
JAN 70	6.50	7.50	0.223	0.188	9.58
JAN 75	3.00	3.60	0.222	0.188	13.36
JAN 80	1.20	1.50	0.213	0.188	17.05
JAN 85	0.40	0.70	0.241	0.188	12.45
JAN 90	0.00	0.50	0.275	0.188	4.66

Figure 5-2 : Sample Output from DATASTREAM Program 201F

B Number of Days Between Dates

The number of days an option has to go to expiration may be found from the following table by subtracting the day number for the present date from that for the expiration date. If the expiration date is beyond the end of the current year, first add 365 to the day number of the expiration date.

Day Number for Each Day of the Year

Day of Mo.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Day of Mo.
1	1	32	60	91	121	152	182	213	244	274	305	335	1
2	2	33	61	92	122	153	183	214	245	275	306	336	2
3	3	34	62	93	123	154	184	215	246	276	307	337	3
4	4	35	63	94	124	155	185	216	247	277	308	338	4
5	5	36	64	95	125	156	186	217	248	278	309	339	5
6	6	37	65	96	126	157	187	218	249	279	310	340	6
7	7	38	66	97	127	158	188	219	250	280	311	341	7
8	8	39	67	98	128	159	189	220	251	281	312	342	8
9	9	40	68	99	129	160	190	221	252	282	313	343	9
10	10	41	69	100	130	161	191	222	253	283	314	344	10
11	11	42	70	101	131	162	192	223	254	284	315	345	11
12	12	43	71	102	132	163	193	224	255	285	316	346	12
13	13	44	72	103	133	164	194	225	256	286	317	347	13
14	14	45	73	104	134	165	195	226	257	287	318	348	14
15	15	46	74	105	135	166	196	227	258	288	319	349	15
16	16	47	75	106	136	167	197	228	259	289	320	350	16
17	17	48	76	107	137	168	198	229	260	290	321	351	17
18	18	49	77	108	138	169	199	230	261	291	322	352	18
19	19	50	78	109	139	170	200	231	262	292	323	353	19
20	20	51	79	110	140	171	201	232	263	293	324	354	20
21	21	52	80	111	141	172	202	233	264	294	325	355	21
22	22	53	81	112	142	173	203	234	265	295	326	356	22
23	23	54	82	113	143	174	204	235	266	296	327	357	23
24	24	55	83	114	144	175	205	236	267	297	328	358	24
25	25	56	84	115	145	176	206	237	268	298	329	359	25
26	26	57	85	116	146	177	207	238	269	299	330	360	26
27	27	58	86	117	147	178	208	239	270	300	331	361	27
28	28	59	87	118	148	179	209	240	271	301	332	362	28
29	29	*	88	119	149	180	210	241	272	302	333	363	29
30	30		89	120	150	181	211	242	273	303	334	364	30
31	31		90		151		212	243		304		365	31

* Add 1 to the numbers after this date if a leap year.

Source : Cleeton, C. E. "Strategies for the Options Trader", John Wiley & Sons, Inc., 1979 p157

Figure 5-3 : Julian Dates Calendar

```
DATASTREAM:  28V
THIS PROGRAM DISPLAYS UP TO 104 VALUES FOR ANY SERIES OR EXPRESSION
ENTER ? IF HELP IS REQUIRED

SERIES OR EXPRESSION (C)  ECNLG1Y________________________________

DISPLAY FREQUENCY    (O)  D          D,W,M,Q,Y OR BLANK

START DATE           (O)  1/5/88__   EG. DD/MM/YY OR MM/YY OR -3M,-30D ETC...

END   DATE           (O)  31/8/88_


C=COMPULSORY, O=OPTIONAL

28V  LONDON-EURO-CURRENCY GUILDER 1 YEAR - MIDDLE RATE              29/12/88
```

WEEK COMMENCING	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
2/ 5/88	N/A	4.250	4.250	4.250	4.250
9/ 5/88	4.438	4.438	4.500	4.563	4.563
16/ 5/88	4.438	4.375	4.375	4.125	4.125
23/ 5/88	4.125	4.375	4.375	4.375	4.500
30/ 5/88	N/A	4.500	4.500	4.500	4.500

Figure 5-4 : Sample Output from DATASTREAM Program 28V

References

Adam, N. and Peagam, N. "A Bullish Outlook for Amsterdam", in **Euromoney Supplement : Survey of the Amsterdam Stock Exchange**, May 1985

Beckers, S. "Standard Deviations Implied in Option Prices as Predictors of Future Stock Price Variability", **Journal of Banking and Finance**, 1981 pp363-381

Black, F. "Fact and Fantasy in the Use of Options", **Financial Analysts Journal**, July-August 1975 pp36-72

Bookstaber, R. "Observed Option Mispricing and the Nonsimultaneity of Stock and Option Quotations", **Journal of Business**, 1981 pp141-155

Cleeton, C. E. "**Strategies for the Options Trader**", John Wiley & Sons, Inc., 1979

DATASTREAM **Traded Options Services Users' Manual**

European Options Exchange "**Trading Rules, April 1981**"

Galai, D. "**Pricing of Options and the Efficiency of the Chicago Board Options Exchange**", Unpublished Ph.D. dissertation, University of Chicago, 1975

Galai, D. "Tests of Market Efficiency of the Chicago Board Options Exchange", **Journal of Business**, 1977 pp167-197

Jarrow, R. and Rudd, A. "**Option Pricing**", Richard D. Irwin Inc, 1983

Keane, S. "**Stock Market Efficiency**", Philip Allan Publishers Limited, 1983

Kerruish, A. "An Empirical Test of the Black-Scholes Option Pricing Model in the UK and Implications for Market Efficiency", Presented to the **European Finance Association Meeting**, September 1985

Phillips, S. and Smith, C. "Trading Costs for Listed Options: The Implications for Market Efficiency", **Journal of Financial Economics**, 1980 pp179-201

Stuart, A. and Ord, K. "**Kendall's Advanced Theory of of Statistics, Volume I : Distribution Theory**", Charles Griffin & Co Ltd, 1987

CHAPTER 6

RESULTS

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Results

6.1 Introduction

The objective of this study is to provide evidence on the efficiency of the stock options market of the European Options Exchange. Efficiency has been defined as the inability of any trader to consistently earn above-normal average rates of return after transactions costs. Following from this definition and the fact that riskless spreading and hedging are used in this study, the null hypothesis to be tested is $H_0 : u = r_f$ and the alternative hypothesis is $H_1 : u > r_f$, where u is the average rate of return from spreading or hedging and r_f is the estimated risk-free interest rate. If the market is efficient, then H_0 cannot be rejected.

The results of the spreading and hedging tests of the null hypothesis are presented in the tables in this chapter and in Appendix 2. The number of spreads, average rate of return and the t-statistic for each class of options, and for the whole sample, are given in each table.

Two sample periods are tested in this study. The first sample period is from 16 August 1988 to 27 September 1988 and the second sample period is from 4 November 1988 to 15 December 1988. Hereinafter, these sample periods will be referred to as Period 1 and Period 2 respectively.

6.2 Spreading Tests

The spreading tests in this study combine options of different series but of the same class, where the under-priced option is bought and the over-priced option is written. Initially, one contract of the under-priced option is bought and an appropriate number of contracts of the over-priced option is written in order to form a riskless position. The number of contracts of the over-priced option written is determined by the hedge ratios of the options in the spread. The spread is then held until the price of one or both legs return to its model value, the mis-pricing of at least one leg is reversed, or until the end of the sample period. The spread is then liquidated. In the case where only one leg's mis-pricing has reversed, only that leg will be liquidated if the remaining leg can be matched with another mis-priced option to form another spread. To maintain a riskless position, the spreads are rebalanced every day throughout the holding period.

6.3 Results of Spreading Tests with DSISD

The results of the spreading tests conducted with data for Period 1 are reported in Tables 6-1, 6-2, 6-3 and 6-4. The data consists of options written on nineteen stocks with 432 series. There are seven stocks with forecasted ex-dividend dates falling within the sample period. For these stocks, all in-the-money series that do not satisfy the Jarrow and Rudd(1983) conditions are excluded from trading. With this exclusion, 388 series remained.

Table 6-1 gives the result of the ex post zero transactions costs test. This test assumed that mispricings detected on day t can be exploited on day t itself. For all options taken as a whole and for each individual class of options (with the exception of NN), the average rates of return from spreading are significantly greater than the risk-free interest rate at the five percent level of significance. The spreading strategy is obviously very profitable. The inference is that the trading rule demonstrated its ability, on average, to identify over-priced and under-priced options. However, this result should not be used to assess the efficiency of the market. In this study, efficiency has been defined as the inability of any trader to consistently generate above-normal average rates of return after transactions costs. A trader who detects mis-priced options on day t may not be able to exploit the mis-pricing by buying (writing) the options immediately. This is especially so for a non-member, or a member of the exchange who is not permitted to trade on the floor of the exchange. Neither can the trader expect to execute the spread on day t+1 using the prices he observed on day t. It is possible that on day t+1 prices have moved against him so that the expected return observed on day t can no longer be earned. A member trader who is permitted to trade on the floor of the exchange may be able to exploit the mis-priced situation almost immediately. However, the *ex post* test results in Table 6-1 have not taken into account transactions costs. Thus, the *ex post* zero transactions costs profits are not profits that a trader would be able to make in practice.

To determine whether significant returns can actually be made by traders who are not permitted to trade on the floor of the exchange, it may be necessary to lag the execution of the spread by some period of time. As daily data is used, the minimum lag is one day. Hence, an *ex ante* test with a one day lag between the formation of the strategy and its implementation is carried out. Table 6-2 gives the results of the *ex ante* test, ignoring transactions costs. The one-day lag in the execution of the spreads has reduced the profitability for all options as a whole, and for 18 out of 19 classes of options. The exception is PHIL. For all options taken as a whole, the average rate of return is not significantly greater than the risk-free interest rate at the five percent level. In six classes the one day delay has turned the significant positive returns into losses. It would seem that in most cases prices converge fairly quickly to their model values, so that many profit opportunities disappear within a day.

Since the average rate of return for all options as a whole is not significantly greater than the risk-free interest rate, the hypothesis of efficiency cannot be rejected at the zero transactions costs level. Thus, further investigation of the hypothesis at the after transactions costs level is redundant; the latter is necessary only when there is a significant average rate of return on a zero transactions costs basis. However, six classes of options have average rates of return that are significantly different from the risk-free interest rate at the five percent level. These are significant returns from the *ex ante* zero transactions costs test. Hence the market still cannot be claimed to be inefficient. The market can be said to be inefficient only if the profits can actually be exploited.

Therefore, it is necessary to determine whether these significant returns persist when transactions costs are taken into account. One component of transactions costs, the bid-ask spread, is taken into account in the *ex ante* test with the bid-ask spread cost, which has to be conducted for these six stocks. The results are presented in Table 6-3, where the results for all other stocks are included in order to maintain the same format for all the tables.

Table 6-3 shows the results of the *ex ante* test with the bid-ask spread cost. The criterion for selecting over- and under-priced options in the presence of bid and ask prices has been described in Chapter Four Section 4.5. The application of this criterion reduces the number of spreads from the *ex ante* zero transactions costs figure of 14657 (Table 6-2) to 2066, an approximately 86 per cent decrease. Quite obviously, a large proportion of the observed deviations of actual prices from model prices occurs within the bounds set by the bid and ask prices.

The result of this *ex ante* test with the bid-ask spread costs shows that all classes of options have negative average rates of return. The bid-ask spread is sufficiently large to ensure that, on average, no positive rates of return are possible. This is certainly the position facing traders who are not permitted to trade on the floor of the exchange.

Thus, with respect to the trading rule used and the sample period studied, the null hypothesis of efficiency cannot be rejected. The market seems efficient to these traders.

It would be of interest to look at the position of the less constrained traders, that is, those who are permitted to trade on the floor of the exchange and who may be able to trade almost immediately upon observing a mis-priced situation. This is done through the _ex post_ test with the bid-ask spread cost.

As discussed in Chapter Four Section 4.3, a lag of one day in the _ex ante_ test may be too long in the case of floor traders who may be able to observe a mis-pricing and trade within a matter of minutes. To approximate this case more closely, an _ex post_ test with the bid-ask spread cost is conducted. The results of this test are given in Table 6-4. The application of the criterion for selecting over-priced and under-priced options in the presence of bid and ask prices again greatly reduces the number of spreads from the _ex post_ zero transactions costs figure of 15424 (Table 6-1) to 2129, an approximately 86 per cent decrease. The bid-ask spread has also eliminated all the significant returns obtained in the zero transactions costs case; all average rates of return are negative. Thus, no significant average rates of return can be earned when the bid-ask spread cost is taken into account. This is so even when it is assumed that a trader can transact immediately upon observing a mis-priced situation.

All average rates of return in Table 6-4 (except AH and AMEV) are higher (less negative) than the average rates of return in Table 6-3. Again, this demonstrates that, on average, the one-day lag in the ex ante test reduces the profitability of the trading rule, an observation that is also evident from comparing the average rates of return in Table 6-1 and Table 6-2.

These results indicate that with respect to this trading rule and the first sample period, the market is efficient in the sense that there are no opportunities for earning above-normal average rates of returns after transactions costs. It is efficient not only to the trader who is not permitted to trade on the floor of the exchange (and is assumed to face a one day delay in transacting when a mis-priced situation is observed), but also to the less constrained trader who is permitted to trade on the floor of the exchange (and is assumed to be able to trade immediately upon observing a mis-priced situation).

Option Code	No. of Spreads	Average Rate of Return	t
All options	15424	4.209	27.33*
ABN	154	4.778	2.94*
AEGN	243	3.329	2.36*
AH	461	5.914	7.81*
AKZO	1888	3.488	9.25*
AMEV	248	14.816	8.59*
AMRO	1095	7.293	11.88*
BUHR	841	4.919	5.76*
ELS	759	3.714	7.22*
GB	1087	7.172	10.56*
HB	551	9.079	7.53*
HO	2215	1.133	2.92*
KLM	677	4.388	5.22*
KNP	2039	2.090	5.61*
NED	1084	5.980	13.56*
NN	146	0.007	-0.02
PHIL	639	2.880	4.83*
RBC	428	5.948	5.64*
RD	324	1.734	2.22*
UNIL	545	2.706	4.54*

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-1 : Results of Ex Post Spreading Test (DSISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	14657	-0.230	-1.84
ABN	142	3.666	1.93*
AEGN	209	0.944	1.01
AH	423	0.587	0.95
AKZO	1807	-1.003	-2.99
AMEV	223	14.811	6.57*
AMRO	1015	3.784	6.25*
BUHR	821	-1.124	-1.73
ELS	728	-1.246	-1.80
GB	1053	0.049	-0.01
HB	515	1.523	1.09
HO	2080	-2.774	-7.39
KLM	677	1.447	1.54
KNP	1963	-4.349	-12.34
NED	1036	-0.350	-0.77
NN	146	-1.886	-1.12
PHIL	589	4.891	7.94*
RBC	403	1.583	2.15*
RD	306	1.499	1.47
UNIL	521	2.516	3.82*

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-2 : Results of *Ex Ante* Spreading Test (DSISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2066	-11.661	-24.72
ABN	44	-30.425	-5.64
AEGN	36	-6.906	-5.77
AH	123	-6.903	-8.67
AKZO	207	-7.316	-4.83
AMEV	44	-8.137	-9.41
AMRO	117	-6.724	-11.65
BUHR	101	-14.784	-8.61
ELS	106	-6.426	-8.13
GB	91	-9.957	-7.03
HB	137	-12.869	-9.04
HO	188	-5.976	-8.03
KLM	67	-5.078	-4.94
KNP	138	-4.642	-7.65
NED	209	-29.190	-18.69
NN	37	-15.410	-3.35
PHIL	60	-15.055	-4.45
RBC	90	-14.536	-7.31
RD	166	-14.022	-4.06
UNIL	105	-7.985	-8.25

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-3 : Results of Ex Ante Spreading Test (DSISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2129	-9.400	-23.76
ABN	46	-25.530	-5.38
AEGN	42	-6.558	-6.85
AH	133	-9.210	-7.77
AKZO	208	-5.442	-5.03
AMEV	47	-9.392	-8.56
AMRO	125	-6.015	-7.56
BUHR	101	-11.024	-10.37
ELS	107	-5.650	-7.48
GB	91	-5.101	-4.89
HB	154	-11.731	-10.88
HO	188	-4.439	-8.26
KLM	67	-4.342	-6.84
KNP	147	-3.856	-7.37
NED	209	-22.020	-17.40
NN	37	-14.130	-3.71
PHIL	60	-9.167	-3.97
RBC	90	-11.584	-7.77
RD	166	-12.060	-3.74
UNIL	111	-5.506	-3.89

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-4 : Results of Ex Post Spreading Test (DSISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

The results of the spreading tests conducted with data for Period 2 are reported in Tables 6-5, 6-6, 6-7 and 6-8. The data consist of options written on nineteen stocks with 401 series. There is only one stock (UNIL) with a forecasted ex-dividend date falling within the test period. For this stock, all in-the-money series that do not satisfy the Jarrow and Rudd(1983) conditions are excluded from trading. With this exclusion, 398 series remained.

Table 6-5 gives the results of the ex post zero transactions costs test. The results are similar to those of the first sample period reported in Table 6-1 All average rates of return are significantly greater than the risk-free interest rate at the five percent level. The spreading strategy again demonstrated its ability, on average, to identify over-priced and under-priced options.

Table 6-6 gives the results of the ex ante test ignoring transactions costs. The results are similar to those of the first sample period presented in Table 6-2 in that, compared to the ex post test, profitability has been reduced for all options as a whole, and for all nineteen classes of options. However, in contrast to the previous period's result, the average rate of return for the whole sample is significantly greater than the risk-free interest rate at the five per cent level. Also, six classes of options have average rates of return significantly greater than the risk-free interest rate at the five per cent level.

Table 6-7 gives the result of the *ex ante* test with the bid-ask spread costs. Again, the application of the criterion for selecting over- and under-priced options in the presence of bid and ask prices reduces the number of spreads from the *ex ante* zero transactions costs figure of 15480 (Table 6-6) to 2033, an approximately 87 per cent decrease. The results of this test show that for the whole sample and for all classes of options, the average rates of return are negative.

Table 6-8 shows the results of the *ex post* test with the bid-ask spread cost. The average rates of return for the whole sample and for individual classes are negative. Again, a large proportion of the mispricings lie within the bid-ask spread : the number of spreads set up is about 87 per cent less than that of the ex post zero transactions costs test.

Option Code	No. of Spreads	Average Rate of Return	t
All options	16057	9.530	39.16*
ABN	542	5.910	8.29*
AEGN	957	8.153	7.68*
AH	781	6.908	9.10*
AKZO	1378	3.678	7.88*
AMEV	805	15.156	15.96*
AMRO	753	8.537	17.03*
BUHR	698	8.980	10.28*
ELS	871	4.464	6.43*
GB	1050	12.935	18.22*
HB	550	5.790	11.68*
HO	1763	6.924	9.73*
KLM	830	15.610	8.64*
KNP	1609	21.501	15.82*
NED	866	5.861	6.37*
NN	705	6.848	6.12*
PHIL	430	5.788	5.34*
RBC	440	11.278	9.51*
RD	671	12.502	13.20*
UNIL	358	1.400	1.86*

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-5 : Results of Ex Post Spreading Test (DSISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	15480	0.533	2.07*
ABN	535	-1.613	-2.55
AEGN	909	3.781	3.56*
AH	776	6.543	7.18*
AKZO	1331	0.555	1.04
AMEV	769	-3.874	-4.48
AMRO	725	2.143	4.10*
BUHR	666	3.936	5.78*
ELS	853	-0.084	-0.20
GB	996	-3.997	-5.82
HB	550	0.077	0.03
HO	1656	2.228	2.86*
KLM	782	-3.745	-1.91
KNP	1527	-2.475	-2.20
NED	860	1.154	1.12
NN	687	5.198	6.00*
PHIL	418	-0.299	-0.39
RBC	440	0.916	0.69
RD	656	0.717	0.72
UNIL	344	1.096	1.13

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-6 : Results of Ex Ante Spreading Test (DSISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2033	-14.346	-25.00
ABN	53	-20.844	-5.47
AEGN	107	-14.645	-6.25
AH	93	-9.721	-7.41
AKZO	184	-9.476	-7.07
AMEV	105	-14.157	-5.94
AMRO	97	-9.852	-8.42
BUHR	71	-11.009	-6.51
ELS	164	-29.415	-6.69
GB	68	-7.531	-9.52
HB	95	-7.167	-6.71
HO	220	-23.756	-10.16
KLM	15	-11.066	-3.82
KNP	106	-15.608	-10.09
NED	318	-14.649	-13.01
NN	60	-11.800	-5.60
PHIL	47	-8.116	-4.05
RBC	79	-11.304	-9.10
RD	61	-1.811	-3.69
UNIL	90	-8.969	-5.83

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-7 : Results of Ex Ante Spreading Test (DSISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2053	-11.023	-25.29
ABN	54	-17.640	-6.26
AEGN	107	-11.186	-5.15
AH	93	-8.300	-6.24
AKZO	185	-5.660	-7.81
AMEV	105	-7.603	-5.04
AMRO	97	-6.850	-5.93
BUHR	75	-8.920	-7.18
ELS	164	-17.905	-7.55
GB	68	-5.390	-7.22
HB	98	-4.712	-6.52
HO	223	-16.568	-7.93
KLM	17	-6.140	-2.21
KNP	112	-11.435	-7.38
NED	318	-16.949	-13.70
NN	60	-8.605	-5.46
PHIL	47	-3.856	-3.29
RBC	79	-10.088	-8.68
RD	61	-1.855	-4.38
UNIL	90	-7.655	-5.75

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-8 : Results of <u>Ex Post</u> Spreading Test (DSISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

Therefore, the results of the second sample period are consistent with those of the first sample period. The conclusion remains unchanged, that is, with respect to the trading rule used and the second sample period, the market appears to be efficient even to the less constrained trader who is assumed to be able to transact immediately upon observing a mis-priced situation. The null hypothesis of efficiency cannot be rejected in any of the two periods. The persistence of market efficiency over both sample periods makes it possible to believe with a greater degree of confidence that the market is likely to be efficient in the future than if only one period is tested, or if the efficiency is not persistent over both periods.

6.4 Tests with Alternative Estimators of the Volatility of the Underlying Stock's Return

The importance of having an accurate estimate of the standard deviation of the stock's return and the difficulty of estimating this input had been discussed in Chapter Four Section 4.2. Because of the importance of this input and the difficulty of estimating it, it is possible that the results may be sensitive to alternative estimators of this input and the conclusions may be different. In Chapter Four Section 4.2 it was argued that three estimators of the standard deviation of the stock's return had to be selected for testing, and the reasons for the choice of these three estimators of the standard deviation of the stock's return were given. The results of the tests of the trading rule with one estimator, the DSISD, have been presented above. The results of the tests with two alternative estimators, the Chiras and Manaster weighted implied standard deviation (CMISD) and the implied standard deviation of the option most sensitive to changes in the standard deviation of the underlying stock's return (AMISD), are reported below.

6.5 Results of Spreading Tests with CMISD

The results of the spreading tests with CMISD conducted with data from Period 1 and Period 2 are presented in tables A2-1 to A2-4 and A2-5 to A2-8 respectively in Appendix 2.

In the ex post tests, all classes of options (except PHIL in the second sample period) have average rates of return that are significantly greater than the risk-free interest rate at the five per cent level (Tables A2-1 and A2-5); in the ex ante tests, profitability is less than the ex post tests for all stocks (except HB in the first sample period) but overall, the average rates of return are still significantly greater than the risk-free interest rate (Tables A2-2 and A2-6); in the ex ante tests with the bid-ask spread cost, all average rates of return are negative and the numbers of spreads are greatly reduced compared to the ex ante tests (Tables A2-3 and A2-7); in the ex post tests with the bid-ask spread cost, all average rates of return are not significantly different from the risk-free interest rate at the five per cent level (Tables A2-4 and A2-8).

Hence, the results of the tests with the trading rule using CMISD are generally similar to the results of the tests with DSISD. With respect to the trading rule used and both sample periods, the hypothesis of efficiency cannot be rejected.

6.6 Results of Spreading Tests with AMISD

The results of the spreading tests with AMISD for the sample periods, Period 1 and Period 2, are presented in Tables A2-9 to A2-12 and A2-13 to A2-16 respectively in Appendix 2. The results of the tests with this estimator are also generally similar to the results of the tests with DSISD and CMISD. The conclusion remains unchanged; that is, for the trading rule used and the sample periods, the hypothesis of efficiency cannot be rejected.

6.7 Summary of Results of Spreading Tests

The results of the tests with all three estimators of the standard deviation of the stock's return are broadly similar. The ex post zero transaction costs results showed that, on average, the trading rule worked very well and the inference is that it is able to identify over-priced and under-priced options. However, taking into account just one component of transactions costs, that is, the bid-ask spread, all average rates of return are not significantly different from the risk-free interest rate at the five per cent level. This is so even for the less constrained trader who is assumed to be able to transact immediately upon observing any mis-pricing. Hence, with respect to the trading rule used and both sample periods, the hypothesis of efficiency cannot be rejected.

6.8 Hedging Tests

The hedging test in this study sets up hedges consisting of one contract of an option and $100e^{-DT}N(d_1)$ shares of its underlying stock, where $e^{-DT}N(d_1)$ is the hedge ratio (see Appendix 1 for definition of the parameters). If the option is under-priced, it is bought and the underlying stock sold short; if the option is over-priced, it is written and the underlying stock bought.

The hedge is liquidated when the market price of the option returns to its model value, when the mis-pricing of the option is reversed, or at the end of the sample period.

6.9 Results of Hedging Tests with DSISD

The results of the hedging tests conducted with data from Period 1 are reported in Tables 6-9, 6-10, 6-11 and 6-12.

Table 6-9 gives the results of the ex post zero transactions costs test. For all options as a whole, the average rate of return is significantly different from the risk-free interest rate at the five per cent level. For the individual classes, sixteen out of nineteen classes have significant average rates of return. The hedge trading rule demonstrated its ability, on average, to identify over-priced and under-priced options.

Table 6-10 gives the result of the ex ante test with zero transactions costs. The one day lag in execution of the spreads has greatly reduced the profits. The overall average rates of return is reduced from 3.262 in the ex post zero transactions costs test to 0.206, and it is not significantly different from the risk-free interest rate. As discussed in the sections on spreading tests, if the hypothesis of efficiency cannot be rejected at the zero transactions costs level, then further investigation of the hypothesis at the after transactions costs level is redundant; the latter is necessary only when there is a significant average rate of return on a zero transactions costs basis.

However, there are four stocks (ABN, AMEV, PHIL and RD) with average rates of return significantly greater than the risk-free interest rate at the five per cent level. This is in contrast to the ex post zero transactions costs test where sixteen stocks have significant average rates of return. Even though the overall average rate of return is not significant, the market can still be said to be inefficient if there are exploitable abnormal profits at the individual stock level. Thus the *ex ante* test with the bid-ask spread cost has to be conducted for these four stocks. The results are presented in Table 6-11. The results for all other stocks are also included in order to maintain the same format for all the tables.

Table 6-11 shows that two of the four stocks that have significant returns in the zero transactions costs case (AMEV and PHIL), now have negative average rates of return. The bid-ask spread cost is sufficiently large to eliminate all the profits. One of the four (ABN) still has a positive rate of return, but it is not significantly different from the risk-free interest rate. Thus the hypothesis of efficiency cannot be rejected.

However, one stock (RD) has a significant (at five per cent) average rate of return after the bid-ask spread cost has been taken into account. Although it is possible that with commissions cost this significant average rate of return could become non-significant or even negative, for members of the exchange who do not incur commissions cost, this might have been an opportunity to earn an above-normal average rate of return. Hence, the market is inefficient during this sample period at least to members of the exchange who do not need to pay commissions. However, it would be of interest to know whether such above-normal profit opportunities are likely to continue to exist in the future. If such opportunities are found to be persistent over time, then it is more likely that they might continue to exist in the future. To see whether the significant average rate of return for the stock RD is to some extent persistent over time, it is necessary to examine the results of the second sample period.

The results of the *ex post* test with the bid-ask spread cost are given in Table 6-12. The overall average rate of return is negative. All average rates of return for the individual stocks are not significantly greater than the risk-free interest rate at the five per cent level.

To summarise, the results in the first sample period show that an above-normal average rate of return after transactions costs could be earned at least by members of the exchange if the *ex ante* hedge trading rule had been applied to the stock RD. To see whether such an inefficiency is persistent over time, it is necessary to examine the results of the second sample period.

Option Code	No. of Spreads	Average Rate of Return	t
All options	1929	3.262	10.65*
ABN	38	5.299	2.38*
AEGN	50	6.103	1.50
AH	65	2.988	2.34*
AKZO	186	1.745	3.22*
AMEV	52	7.631	2.41*
AMRO	130	2.610	3.79*
BUHR	114	4.463	3.98*
ELS	108	1.103	1.94*
GB	142	3.961	3.51*
HB	94	5.323	2.98*
HO	190	1.932	6.54*
KLM	95	4.033	4.06*
KNP	193	1.528	4.89*
NED	124	6.517	2.66*
NN	38	7.784	2.57*
PHIL	97	1.283	3.69*
RBC	71	5.600	2.15*
RD	59	1.705	1.04
UNIL	83	0.834	1.54

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-9 : Results of <u>Ex Post</u> Hedging Test (DSISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1844	0.206	0.36
ABN	35	10.278	1.71*
AEGN	45	-1.795	-1.50
AH	60	-1.854	-1.37
AKZO	177	-0.332	-1.26
AMEV	47	3.466	1.79*
AMRO	125	0.142	0.12
BUHR	112	-0.241	-0.31
ELS	105	-1.555	-3.08
GB	139	-1.047	-2.14
HB	90	-0.567	-0.81
HO	181	-0.397	-1.77
KLM	95	-1.216	-2.02
KNP	187	-0.668	-1.46
NED	122	-3.482	-2.90
NN	38	3.000	0.84
PHIL	89	0.581	1.74*
RBC	66	0.491	0.33
RD	53	21.864	1.83*
UNIL	78	-1.821	-2.62

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-10 : Results of Ex Ante Hedging Test (DSISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	563	-2.727	-4.30
ABN	20	1.666	0.66
AEGN	16	-1.347	-4.04
AH	27	-3.965	-2.40
AKZO	44	-3.070	-3.54
AMEV	19	-1.357	-2.41
AMRO	32	-2.571	-3.68
BUHR	29	-1.639	-3.07
ELS	29	-3.647	-4.41
GB	26	-1.354	-1.93
HB	45	-5.275	-2.65
HO	43	-2.593	-4.83
KLM	17	-1.414	-2.68
KNP	36	-2.273	-2.28
NED	46	-12.457	-3.03
NN	16	-3.187	-3.49
PHIL	23	-1.602	-4.90
RBC	29	-6.661	-1.58
RD	38	10.368	1.70*
UNIL	28	-3.328	-3.60

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-11 : Results of <u>Ex</u> <u>Ante</u> Hedging Test (DSISD) with the Bid-Ask Spread Cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	578	-1.436	-3.18
ABN	21	1.413	0.68
AEGN	17	-1.219	-3.28
AH	29	-3.511	-2.72
AKZO	44	-1.001	-1.86
AMEV	20	-1.587	-2.23
AMRO	34	-1.067	-1.40
BUHR	29	-0.839	-1.21
ELS	29	-3.760	-3.59
GB	26	0.116	0.06
HB	47	-2.768	-3.41
HO	43	-2.240	-4.41
KLM	17	-1.454	-2.64
KNP	37	-1.557	-2.62
NED	46	4.442	1.46
NN	16	-2.021	-2.84
PHIL	23	-0.540	-0.82
RBC	29	-0.007	-0.03
RD	42	-5.957	-1.29
UNIL	29	-3.288	-3.89

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table 6-12 : Results of <u>Ex Post</u> Hedging Test (DSISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

The results of the hedging tests for Period 2 are presented in Tables 6-13, 6-14, 6-15 and 6-16.

Table 6-13 gives the results of the <u>ex post</u> zero transactions costs test. Unlike the results of the first sample period, in this period all classes of options have average rates of return that are significantly greater than the risk-free interest rate at the five per cent level. The trading rule worked very well in all cases.

The results of the <u>ex ante</u> test are shown in Table 6-14. The one day delay in the execution has turned the overall average rate of return negative. Only two stocks (AH and HB) have average rates of return that are significantly greater than the risk-free interest rate. When the bid-ask spread cost is taken into account in the <u>ex ante</u> test, the average rates of return for these two stocks turned negative (Table 6-15).

The results of the <u>ex post</u> test with the bid-ask spread cost are given in Table 6-16. All average rates of return are not significantly greater than the risk-free interest rate at the five per cent level.

Option Code	No. of Spreads	Average Rate of Return	t
All options	2200	4.515	13.98*
ABN	101	3.691	3.87*
AEGN	140	6.754	4.06*
AH	103	6.793	4.92*
AKZO	154	3.348	4.30*
AMEV	120	4.435	5.70*
AMRO	105	2.028	2.72*
BUHR	102	4.710	3.09*
ELS	122	3.941	4.88*
GB	139	3.254	6.11*
HB	80	2.151	3.44*
HO	172	4.095	3.70*
KLM	135	7.917	2.68*
KNP	182	3.975	4.21*
NED	119	3.636	2.58*
NN	112	4.880	4.65*
PHIL	85	7.101	3.90*
RBC	72	4.545	3.23*
RD	89	4.783	2.09*
UNIL	68	3.473	3.81*

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-13 : Results of Ex Post Hedging Test (DSISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2127	-0.678	-3.05
ABN	100	-1.382	-2.91
AEGN	137	-0.264	-0.23
AH	102	2.266	1.91*
AKZO	150	-1.539	-2.72
AMEV	115	-1.862	-1.98
AMRO	101	-0.846	-1.44
BUHR	98	-0.118	-0.22
ELS	116	0.232	0.33
GB	133	0.018	-0.06
HB	80	2.521	1.91*
HO	164	-0.724	-1.07
KLM	127	-3.733	-1.94
KNP	174	0.685	0.71
NED	113	0.276	0.31
NN	109	-1.332	-1.43
PHIL	82	-1.806	-1.63
RBC	72	-3.097	-1.49
RD	88	-1.915	-2.52
UNIL	66	-0.932	-1.40

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-14 : Results of *Ex Ante* Hedging Test (DSISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	605	-4.142	-10.44
ABN	23	-3.895	-3.35
AEGN	35	-6.738	-3.80
AH	29	-1.877	-5.35
AKZO	40	-3.325	-2.02
AMEV	29	-3.337	-2.35
AMRO	30	-3.159	-4.37
BUHR	23	-2.349	-3.31
ELS	46	-5.168	-2.74
GB	21	-2.138	-3.85
HB	25	-0.659	-0.81
HO	49	-4.262	-2.51
KLM	23	-4.475	-2.46
KNP	41	-5.082	-3.28
NED	64	-6.099	-3.04
NN	25	-4.403	-2.55
PHIL	23	-4.009	-2.76
RBC	24	-3.340	-2.41
RD	26	-4.970	-2.34
UNIL	29	-4.352	-2.75

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-15 : Results of <u>Ex Ante</u> Hedging Test (DSISD) with the Bid-Ask Spread Cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	611	-1.580	-6.81
ABN	23	-1.462	-1.53
AEGN	35	-3.585	-4.06
AH	29	-0.981	-3.11
AKZO	40	-0.296	-2.05
AMEV	29	-1.487	-3.17
AMRO	30	-2.212	-4.34
BUHR	24	-2.363	-3.51
ELS	46	-0.988	-2.15
GB	21	-1.348	-4.15
HB	26	-0.736	-2.20
HO	49	-2.441	-3.83
KLM	23	0.912	0.33
KNP	42	-0.504	-0.66
NED	67	-3.819	-2.69
NN	25	-1.603	-3.22
PHIL	23	1.470	0.97
RBC	24	-2.320	-1.88
RD	26	-2.009	-5.65
UNIL	29	-0.584	-0.94

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table 6-16 : Results of <u>Ex</u> <u>Post</u> Hedging Test (DSISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

Hence, in the second sample period there are no opportunities for earning above-normal average rates of return and the market is efficient even to the less constrained trader who is assumed to be able to transact immediately upon observing any mis-pricing.

In the first sample period, the ex ante hedge trading rule generated an above-normal average rate of return for the stock RD. This above-normal profit opportunity did not persist into the second sample period : the average rate of return for the stock RD in the ex ante test with the bid-ask spread cost is negative. Since the criterion of persistence is not met, it can be argued that with the available evidence, the inefficiency observed in the first sample period is not likely to be exploitable.

6.10 Results of Hedging Tests with CMISD

The results of the hedging tests for Period 1 and Period 2 are presented in Tables A2-17 to A2-19 and A2-20 to A2-23 respectively in Appendix 2. The results of the tests with the CMISD follow a a pattern similar to the results of the tests with the DSISD : in the ex post test, all classes of options (except PHIL in both sample periods) have significant average rates of return (Tables A2-17 and A2-20); in the ex ante test, the one day lag has turned the overall _ex post_ profits in both periods into losses (Tables A2-18 and A2-21). In the first sample period, no individual class of options has an _ex ante_ zero transactions costs average rate of return significantly greater than the risk-free interest rate. Hence, the _ex ante_ test with the bid-ask spread cost is redundant as the returns from this test must be lower than the zero transactions costs test and therefore cannot be significantly greater than the risk-free interest rate. In Period 2 one stock (NED) has a significant ex ante average rate of return (Table A2-21), but this turned negative when the bid-ask spread cost is taken into account (Table A2-22). The results of the ex post tests with the bid-ask spread cost are given in Tables A2-19 and A2-23. All average rates of return are not significantly greater than the risk-free interest rate. Hence, with respect to the trading rule with the CMISD and the sample periods studied, the hypothesis of efficiency cannot be rejected at the five per cent level.

6.11 Results of Hedging Tests with AMISD

The results of the hedging tests for Period 1 and Period 2 are presented in Tables A2-24 to A2-27 and A2-28 to A2-31 respectively in Appendix 2. The results are broadly similar to the results of the tests with the DSISD and the CMISD. There are no opportunities for earning above-normal average rates of return after transactions costs. Hence, with respect to the trading rule used and the sample periods studied, the hypothesis of efficiency cannot be rejected at the five per cent level.

6.12 Summary of Results of Hedging Tests

The results of the hedging tests with all three estimators of the volatility of the stock's return are broadly similar. The *ex post* zero transactions costs results show that the trading rule worked very well in most cases and the inference is that it is able to distinguish between over-priced and under-priced options. However, the bid-ask spread cost is large enough to eliminate the abnormal profits in nearly all cases (except for the stock RD in the first sample period) so that the average rates of return are not significantly different from the risk-free interest rate at the five per cent level. With the exception of the stock RD in the first sample period, the hypothesis of efficiency cannot be rejected . However, the above-normal average rate of return for RD in the first sample period did not persist into the second period and therefore, with the available evidence, the inefficiency is regarded as not exploitable.

6.13 Comparison with results of some other studies

Van der Hilst(1980) concluded that the EOE was not perfectly efficient, but his study ignored transactions cost (see Chapter Three Section 3.2). The results of this study show that although average abnormal profits were available before transactions cost were taken into account, these profits turned into losses when the bid-ask spread cost was accounted for.

The findings of this study are also broadly consistently with those of other studies. For example, Blomeyer and Klemkosky(1983) tested the efficiency of the Chicago Board Options Exchange using a hedging strategy. They found that although the *ex post* returns were statistically significant at the five per cent level, the *ex ante* returns after transactions costs were not. Their results supported option market efficiency.

On the other hand, Galai(1977) used both spreading and hedging strategies and found that the Chicago Board Options Exchange was less than perfectly efficient. However, as Phillips and Smith(1980) pointed out, it is likely that the transactions costs in Galai's study were under-estimated. Phillips and Smith showed that after taking into account the bid-ask spread cost that

Phillips and Smith themselves estimated, the abnormal profits in Galai's study were eliminated, a result that is consistent with market efficiency.

Bhattacharya(1983) found that his spreading test of the Chicago Board Options Exchange produced abnormal returns even after transactions costs were taken into account. This would seem to be inconsistent with the findings of this study. However, Bhattacharya's result must be treated with caution since his fortnightly revision of spreads cannot maintain riskless spreads positions.

In the UK, options market efficiency tests have been conducted by Kerruish(1984) and Gemmill and Dickins(1986). Kerruish(1984) found the London Traded Options Market (LTOM) to be efficient. Gemmill and Dickins(1986) found statistically significant profits in excess of the risk-free interest rate. However, these profits turned into losses when the bid-ask spread was applied. These results are therefore consistent with the evidence in this study.

6.14 Summary and Conclusions

In this study, a market is said to be efficient if no trader can consistently earn an above-normal average rate of return after transactions costs. The evidence presented in this chapter shows that with respect to the trading rules used and the sample periods studied, there have been no persistent opportunities in the stock options market of the EOE for earning above-normal average rates of return after transactions costs. Hence, the stock options market of the EOE can be said to be efficient.

References

Bhattacharya, M. "Transactions Data Test of Efficiency of Chicago Board Options Exchange", **Journal of Financial Economics**, 1983 pp161-185

Blomeyer, E. C. and Klemkosky, R. C. "Tests of Market Efficiency for American Call Options", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath and Co., Lexington Books, 1983

Galai, D. "Tests of Market Efficiency of the Chicago Board Options Exchange", **Journal of Business**, 1977 pp167-197

Gemmill, G. and Dickins, P. "An Examination of the Efficiency of the London Traded Options Market", **Applied Economics**, 1986 pp995-1010

Jarrow, R. and Rudd, A. "**Option Pricing**", Richard D. Irwin Inc, 1983

Kerruish, A. "An Empirical Test of the Black-Scholes Option Pricing Model in the UK and Implications for Market Efficiency", Presented to the **European Finance Association Meeting**, September 1985

Phillips, S. and Smith, C. "Trading Costs for Listed Options: The Implications for Market Efficiency", **Journal of Financial Economics**, 1980 pp179-201

Van der Hilst, J. "Marktefficiency op de EOE te Amsterdam", in **Financiering en Belegging**, stand van zaken anno 1980, Ballendux, F. J. (ed), Erasmus Universiteit, Rotterdam (1980)

CHAPTER SEVEN

SUMMARY, CONCLUSIONS AND LIMITATIONS

Chapter Contents

Chapter Seven Page

Summary, Conclusions and Limitations

7.1 Introduction

This chapter provides a summary of the methodology, results and conclusion of this study and highlights its limitations. It ends with some suggestions for future research.

7.2 Summary and Conclusions

The objective of this study is to provide evidence on the efficiency of the stock options market of the EOE. Efficiency has been defined as the inability of any trader to consistently earn above-normal average rates of return after transactions costs.

The hypothesis of efficiency is tested with spreading and hedging strategies on stock options. The trading rule uses DATASTREAM's option pricing model, that is, the Black-Scholes model with Merton's dividend adjustment (see Appendix 1), to identify mispriced options. The model is assumed to be correct so that any deviation of the market price from DATASTREAM's model price is taken as a signal to buy or write the option. Riskless spreads are set up with over-priced and under-priced options on the same stock and held until the mispricing of at least one leg of the spread is reversed, or until the end of the sample period. 'Riskless' hedges, however, are set up with these mispriced options and their underlying stocks and held until the mispricing of the option in the hedge is reversed, or, until the end of the sample period. During the period the hedges and spreads are held, daily rebalancing is employed to maintain riskless positions.

The sensitivity of the results to alternative estimators of the standard deviation of the stock's return is also tested by using two variations of the trading rule. In each case, the same model is used but with a different estimator of the standard deviation of the underlying stock's return as input to the model.

The results of these tests of the efficiency of the EOE are summarised as follows :

i) the spread trading rule using the DATASTREAM option pricing model to identify mispriced options performed very well in the ex post tests. The inference is that it is able to identify over-priced and under-priced options,

ii) delaying the execution and liquidation of the spreads by one day greatly reduces the profitability of the trading rule, indicating that actual prices converge fairly quickly to model prices during the one day lag. The average rate of return is, however, still significantly different from the risk-free interest rate for at least some classes of options,

iii) introduction of the bid-ask spread cost eliminates all profit opportunities in both the ex ante and the ex post tests,

iv) the lack of profit opportunities on an after transactions costs basis is persistent over both sample periods,

v) a large proportion (around eighty six per cent) of the deviations of the actual price from the model price occurs within the bounds set by the bid and ask prices,

vi) the results of the hedging tests are generally similar to those of the spreading tests,

vii) using two alternative estimators of the standard deviation of the stock's return as input to the model changes the results quantitatively, but makes no difference to the conclusion.

The conclusion is that during the sample periods studied, the EOE is efficient with respect to the trading rule used. Although market prices do deviate from model prices, no persistent profit opportunities exist for any trader. Even a member of the exchange trading on the floor of the EOE and assumed to be able to trade immediately upon observing a mispricing, is not able to earn an above-normal average rate of return when the bid-ask spread cost is taken into account.

The implication for investors in this market is that attempts to identify mispriced options either through their own efforts or by relying on recommendations of investment analysts will be a waste of resources.

7.3 Limitations

This study has several limitations :

i) The EOE is found to be efficient only with respect to the trading rules used. However, this does not diminish the importance of this evidence. The nature of such evidence is cumulative and can never be conclusive. Keane(1983) noted that "despite the fact that the statistical method provides the only vehicle for establishing a case in favour of or against market efficiency, even this can never be capable of providing conclusive proof". Furthermore, Fama(1970)'s observation on the nature of the evidence for semistrong form tests of stock market efficiency is also relevant here. He noted that "each individual test, however, is concerned with the adjustment of security prices to one kind of information generating event .... Thus each test only brings supporting evidence for the model, with the idea that by accumulating such evidence the validity of the model will be 'established'". (p404).

Although the trading rules used have been shown to perform very well in the ex post zero transactions costs tests, it may be possible for other trading rules, such as those using different models or different estimators for the inputs to produce superior results. Less mechanistic trading strategies may also be more profitable but such trading strategies may not be amenable to testing. As Gastineau(1988) observed that "certain investors and portfolio managers have obtained superior results over long periods. The art or science of market efficiency testing has not yet reduced the techniques used by these investors and managers to testable decision rules". The possibility of existence of such profitable trading rules does not, however, imply that the market is inefficient. Keane(1983) argued that "even if one believes that a small proportion of the many trading rules on offer in the market at any given time is likely to be successful, this confidence is of little practical significance until the successful strategies are identified and distinguished from the rest" (p61).

ii) The bid and ask price quotations used in this study are valid for five contracts only. EOE Trading Regulations 7B(ii) stipulates that market makers and floor traders are not obliged to buy or sell more than five contracts at the prices they quote. Hence, when the trading rule requires more than five contracts to be bought, written or sold, there is no assurance that it can be done at the quoted bid and ask prices. Contracts in excess of five may have to be bought at a price higher than the quoted ask price or written (or sold) at a price lower than the quoted bid price. Thus, assuming that the price quotations are valid for more than five contracts will bias the results against efficiency.

iii) Assuming that the bid-ask spread cost is equal to the whole of the quoted bid-ask spread may overstate this component of transactions costs because in some cases transactions may occur within the quoted spread. This will bias the results in favour of efficiency.

In order to mitigate the effect of this bias, an additional <u>ex post</u> test with 80 per cent, instead of

100 per cent, of the bid-ask spread cost was carried out. The *ex post* test was used and only the DSISD estimator was tested because earlier results had shown that the conclusion is not sensitive to other estimators of the standard deviation of the underlying stock's return and that generally the *ex post* tests produced results that are superior to those of the *ex ante* tests. The choice of 80 per cent is arbitrary. Whether an average discount of 20 per cent overstates or understates the actual bid-ask spread cost is a matter for future research.

The results of this test are presented in Tables A3-1 to A3-4 in Appendix 3. All average rates of return (with the exception of NED in Period 1 hedging test) are not significantly greater than the risk-free interest rate. There are no persistent opportunities for earning above-normal average rates of return after taking into account 80 per cent of the bid-ask spread cost. The conclusion of market efficiency remains unchanged.

iv) The use of daily closing price quotations also has its limitations. With daily closing price quotations, it is not possible to use a more realistic lag in setting up and liquidating the spreads and hedges. Studies that used intra-day transactions data, for example, Blomeyer and Klemkosky(1983), can allow for lags of five minutes and fifteen minutes between the identification of the mispricing and the execution of the spread. In this study, the two extremes of no lag (ex post test) and a one-day lag (ex ante test) are examined (see Chapter Four Section 4.3). The results of this study show that the profitabililty of the ex ante tests are generally greatly reduced when compared to the ex post tests (see Chapter Six), implying that delays in execution are costly. Hence, compared to lags of five minutes and fifteen minutes, generally the no lag case biases the results against efficiency and the one-day lag case biases it in favour of efficiency.

v) For various reasons, the spreads and hedges in this study are not entirely riskless. First, in the ex ante test, the delay in executing the spreads and hedges leads to risky positions because with the delay, the prices at which the spreads and hedges are executed may not be the same as those with which the mispricings are observed. Returns are influenced by price drifts during the delay.

Second, the Leland(1985) modification to the hedge ratio has not been used. Leland showed that if his modified hedge ratio is not used, riskless hedging is not possible in the presence of transactions costs.

However, the Leland modified hedge ratio is ignored in this study because of the difficulty of obtaining an accurate estimate of the bid-ask spread for input into the modified hedge ratio (see Chapter Four Section 4.6).

Third, with bid and ask prices it is possible to calculate two ISDs for each option by equating the model price to the bid and ask prices respectively. Let the ISD calculated using the bid price be ISD_{BID} and the ISD calculated using the ask price be ISD_{ASK}. By using ISD_{BID} and ISD_{ASK} as estimators of the standard deviation of the underlying stock's return, two corresponding hedge ratios can be computed. It may be that hedge ratios calculated using these ISDs can lead to riskless hedging. For example, Bhattacharya(1983) stated that the neutral hedge ratio for a spread consisted of buying $N(d_1)_m$ / $N(d_1)_n$ contracts of n for each contract of m sold, where $N(d_1)_m$ is the hedge ratio of option m calculated using ISD_{bid} and $N(d_1)_n$ is the hedge ratio of option n calculated using ISD_{ASK}. Presumably, since option m is to be sold and it is assumed that it will be sold at the bid price, therefore, the hedge ratio $N(d_1)_m$ is used for option m. Similarly, since option n is to be bought and it is assumed that it will be bought at the ask price, therefore, the hedge ratio $N(d_1)_n$ is used for option n. However, there has been no formal proof that using these hedge ratios will lead to riskless positions.

This study uses the mid-market price ((bid + ask) / 2) to calculate the ISDs for input into the hedge ratio calculation. Hedges and spreads set up using these hedge ratios may not be riskless.

However, even if the spreads and hedges in this study are not riskless, this limitation is not critical to this study since no inefficiencies had been found. If any inefficiency has been found, the question would arise as to whether the use of a estimated risk-free interest rate as the expected average rate of return is appropriate.

vi) The distributions of all the rates of return for tests using the DSISD estimator are skewed. The values of the skewness measure are given in Tables A4-1 to A4-4 in Appendix 4.

In the case of skewed distributions, the mean, the median and the mode are all likely to differ from one another. Which of these should be used as a summary measure of the distribution ? The choice is arbitrary as statistical theory does not provide any guidance. Hoaglin, Mosteller and Tukey(1983) stated that "this is not a question a statistician alone should try to resolve .....". This study uses the mean since it is a commonly used measure.

However, in order to determine whether the conclusion is sensitive to the use of an alternative measure, the median, a non-parametric SIGN test is carried out on the returns of the <u>ex post</u> test with 80 per cent of the bid-ask spread cost, using the DSISD estimator.

The SIGN test is used to test the null hypothesis $H_0 : m = r_f$ against the alternative hypothesis $H_1 : m > r_f$ where m is the median rate of return and r_f is the estimated risk-free interest rate. The one-sample SIGN test is described in detail in Hoel(1971) p310-311.

The results of this test are presented in Tables A4-5 and A4-6 in Appendix 4. They are consistent with those obtained using the mean. In all cases, the null hypothesis cannot be rejected at the five per cent level of significance implying that none of the median rates of return are significantly greater than the risk-free interest rate at the five percent level. Therefore, the conclusion of market efficiency remains unchanged.

vii) Finally, this study tests the joint hypothesis of model validity, input accuracy and market efficiency. Model validity and input accuracy have been assumed in order to draw inferences with regard to market efficiency.

7.4 Suggestions for future research

This study has shown that the bid-ask spread cost is the main reason for the inability of the trading rule to generate above-normal average rates of return after transactions costs. The trading rule has been shown to be highly profitable on an ex post before transactions costs basis. But, whether the bid-ask spread cost on the EOE is relatively higher than those of other markets remains to be investigated. If it is, it would be interesting to determine the reasons for the large bid-ask spreads and whether they are consistent with the risks borne by market makers.

The EOE assigns at least four market makers to each option class to ensure a competitive market place (see Chapter Two Section 2.5). Thus, it may be unlikely that bid and ask spreads will be relatively large due to a lack of competition. However, if market makers on the EOE do not act independently, then it may be possible for large bid-ask spreads to be due to a lack of competition. For example, market makers on the

London Traded Options Market had been described as a "close-knit 'cosy cartel of old style jobbers'" (Financial Times 20 June 1989). It is not known whether EOE market makers behave in the same way.

This study ignored the question of the depth of the market, that is, the number of contracts that can be traded at a given price. It is assumed that any number of contracts can be bought or written at the quoted price. Future research should use transaction-by-transaction data to test this aspect of the market. Also, with transactions data a more realistic lag than that used in this study is possible. Although transactions data can overcome some problems, it also has its limitations, as Galai(1983b) stated : "Stored data may mislead, even when refined transaction data are used". Galai suggested that "ex ante efficiency tests should be carried out on the floor of the exchange by monitoring, on real time, the opportunities available to market participants".

This study has also emphasised the problem of the joint hypotheses of model validity, input accuracy and market efficiency. Model validity and input accuracy have been assumed in order to test for market efficiency. Future research could try to decompose these joint hypotheses and analyse each separately.

Tests should also be conducted with other trading rules. However, this study has shown that the impact of the bid-ask spread cost on trading profits is non-trivial and hence, it may be unlikely that above-normal profits can be generated with mechanistic trading rules. Tests with less mechanistic trading strategies, as mentioned by Gastineau(1988) (see Section 7.3 of this Chapter), may be more worthwhile if those strategies can be identified and made amenable to testing.

References

Bhattacharya, M. "Transactions Data Test of Efficiency of Chicago Board Options Exchange", **Journal of Financial Economics**, 1983 pp161-185

Blomeyer, E. C. and Klemkosky, R. C. "Tests of Market Efficiency for American Call Options", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath and Co., Lexington Books, 1983

European Options Exchange **"Trading Regulations"**

Fama, E. F. "Efficient Capital Markets : A Review of Theory and Empirical Work", **Journal of Finance**, May 1970 pp383-423

Financial Times 20 June 1989

Galai, D. "A Survey of Empirical Tests of Option Pricing Models", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath & Co., Lexington Books, 1983b

Gastineau, G. **"The Options Manual"**, McGraw-Hill Book Co, 1988

Hoaglin, D. C., Mosteller, F. and Tukey, J. W. **"Understanding Robust and Exploratory Data Analysis"**, John Wiley & Sons, Inc., 1983

Hoel, P. G. "**Introduction to Mathematical Statistics**", John Wiley & Sons, Inc., 1971

Keane, S. "**Stock Market Efficiency**", Philip Allan Publishers Limited, 1983

Leland, H. "Option Pricing and Replication with Transactions Costs", **Journal of Finance**, 1985 pp1283-1301

Appendix 1

The Option Pricing Model

The Black-Scholes model with the Merton dividend adjustment is :

$$C = e^{-DT}SN(d_1) - e^{-rT}XN(d_2)$$

where

$$d_1 = (\ln(S/X) + (r - D + 0.5\sigma^2)T) / r\sqrt{T}$$

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

and

C = model price

D = constant known continuous dividend yield

S = share price

X = exercise price

σ = standard deviation of returns on the stock during the period T

r = risk-free interest rate

T = time to expiry

N(.) = cumulative standard normal distribution function

The following assumptions are needed to derive the model :

(a) Short selling is allowed

(b) The option can only be exercised at maturity

(c) The stock pays a constant known continuous dividend with yield D

(d) The risk-free rate is constant through time

(e) There are no transactions costs in the stock and options markets

(f) Assets are divisible

(g) It is possible to borrow at the risk-free rate

(h) The stock price follows a random walk in continuous time with a variance rate proportional to the square of the stock price. Thus the distribution of the possible stock prices at the end of any finite interval is lognormal. The variance rate of return on the stock is constant. (Black and Scholes (1973)).

APPENDIX TWO

RESULTS OF TESTS WITH ALTERNATIVE ESTIMATORS OF THE STANDARD DEVIATION OF THE UNDERLYING STOCK'S RETURN

Option Code	No. of Spreads	Average Rate of Return	t
All options	19838	9.619	42.70*
ABN	215	27.716	6.85*
AEGN	476	13.775	6.43*
AH	752	10.874	14.14*
AKZO	1679	6.092	10.18*
AMEV	435	16.711	7.34*
AMRO	1421	10.295	17.04*
BUHR	1164	11.775	12.67*
ELS	1286	13.090	18.44*
GB	1370	11.172	12.14*
HB	479	6.355	4.80*
HO	3463	7.760	16.53*
KLM	826	14.896	12.52*
KNP	2648	4.230	9.42*
NED	1734	6.119	10.17*
NN	345	19.106	11.48*
PHIL	210	9.586	7.07*
RBC	371	9.154	9.59*
RD	367	24.767	4.69*
UNIL	597	11.776	11.74*

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-1 : Ex Post Spreading Test (CMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	19288	0.764	3.69*
ABN	206	12.783	3.76*
AEGN	476	5.463	2.75*
AH	728	4.576	6.20*
AKZO	1635	-0.904	-1.53
AMEV	421	0.947	0.38
AMRO	1373	3.401	5.53*
BUHR	1146	1.043	1.58
ELS	1230	-0.108	-0.22
GB	1360	-0.682	-1.07
HB	474	8.284	7.03*
HO	3313	-2.343	-6.06
KLM	812	3.987	4.92*
KNP	2567	-1.971	-3.65
NED	1708	1.657	2.41*
NN	345	-2.659	-1.76
PHIL	207	4.966	2.92*
RBC	355	-0.266	-0.47
RD	367	11.392	6.00*
UNIL	565	1.915	2.29*

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-2 : Ex Ante Spreading Test (CMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1086	-13.666	-19.35
ABN	18	-7.441	-8.03
AEGN	35	-36.923	-4.44
AH	49	-11.038	-10.14
AKZO	73	-15.501	-4.18
AMEV	10	-12.083	-3.48
AMRO	78	-10.816	-8.74
BUHR	35	-10.506	-6.72
ELS	62	-10.426	-6.22
GB	34	-11.134	-6.25
HB	55	-21.951	-5.33
HO	98	-8.344	-6.40
KLM	23	-15.404	-2.12
KNP	146	-8.150	-7.97
NED	148	-9.872	-4.84
NN	34	-18.233	-4.26
PHIL	9	-12.472	-6.32
RBC	30	-27.089	-4.21
RD	72	-20.690	-8.02
UNIL	77	-17.157	-5.29

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-3 : Ex Ante Spreading Test (CMISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1106	-9.145	-16.97
ABN	18	-7.015	-7.35
AEGN	37	-32.275	-4.11
AH	49	-9.932	-12.80
AKZO	75	-5.096	-2.73
AMEV	13	-12.376	-4.33
AMRO	78	-8.379	-7.46
BUHR	35	-8.507	-5.96
ELS	65	-7.361	-3.33
GB	34	-5.499	-3.93
HB	55	-14.378	-7.34
HO	102	-5.830	-5.19
KLM	23	-10.160	-2.09
KNP	146	-5.217	-6.67
NED	148	-6.885	-4.51
NN	34	-9.130	-3.73
PHIL	9	-8.053	-6.12
RBC	30	-16.794	-4.34
RD	78	-21.086	-7.61
UNIL	77	-2.810	-2.27

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-4 : Ex Post Spreading Test (CMISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	17979	12.427	42.37*
ABN	264	11.215	5.80*
AEGN	1143	10.904	7.26*
AH	976	17.669	16.95*
AKZO	1359	5.847	9.12*
AMEV	830	12.852	13.19*
AMRO	909	13.052	15.74*
BUHR	701	10.990	11.60*
ELS	855	10.981	12.60*
GB	1072	17.340	18.83*
HB	717	8.833	9.69*
HO	2320	9.672	9.17*
KLM	964	17.921	13.92*
KNP	1675	12.098	10.37*
NED	1352	17.647	10.60*
NN	770	13.921	12.01*
PHIL	118	4.570	1.57
RBC	309	6.032	3.55*
RD	1222	13.604	15.17*
UNIL	423	11.081	9.81*

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-5 : Ex Post Spreading Test (CMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	17406	2.090	7.25*
ABN	264	4.263	2.84*
AEGN	1104	-0.607	-0.38
AH	957	6.266	6.46*
AKZO	1303	-0.483	-0.93
AMEV	804	0.084	0.03
AMRO	897	5.542	7.53*
BUHR	699	-0.178	-0.21
ELS	840	6.263	6.42*
GB	1027	1.485	1.91*
HB	702	1.403	1.36
HO	2253	3.898	3.61*
KLM	934	-5.178	-4.74
KNP	1612	3.548	3.34*
NED	1269	3.413	2.17*
NN	734	0.715	0.69
PHIL	111	-3.265	-1.34
RBC	309	1.503	1.28
RD	1190	3.284	4.18*
UNIL	397	-1.673	-1.35

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-6 : Ex Ante Spreading Test (CMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1006	-14.349	-16.92
ABN	10	-7.388	-6.40
AEGN	26	-9.780	-5.80
AH	56	-14.990	-3.30
AKZO	172	-5.503	-6.51
AMEV	26	-7.519	-3.11
AMRO	29	-12.011	-6.06
BUHR	56	-5.434	-4.36
ELS	33	-38.422	-3.85
GB	14	-20.617	-6.03
HB	37	-11.051	-8.01
HO	135	-22.424	-8.33
KLM	20	-14.728	-4.47
KNP	56	-26.417	-6.82
NED	132	-7.930	-4.27
NN	23	-5.703	-8.33
PHIL	4	-33.638	-1.81
RBC	31	-19.404	-4.29
RD	83	-11.668	-8.01
UNIL	63	-28.954	-4.52

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-7 : _Ex Ante_ Spreading Test (CMISD) with the bid-ask spread cost
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1034	-8.380	-13.58
ABN	10	-6.645	-6.40
AEGN	28	-11.590	-3.92
AH	56	-7.840	-4.25
AKZO	175	-4.336	-3.87
AMEV	26	-5.894	-2.33
AMRO	29	-8.357	-4.61
BUHR	56	-1.544	-1.90
ELS	33	-19.147	-4.05
GB	14	-10.988	-10.79
HB	37	-8.497	-7.95
HO	137	-9.675	-6.30
KLM	20	-6.210	-2.69
KNP	56	-15.401	-6.08
NED	139	-0.861	-0.77
NN	26	-14.475	-2.38
PHIL	5	-23.756	-1.86
RBC	31	-10.372	-5.34
RD	93	-11.008	-5.75
UNIL	63	-19.219	-3.31

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-8 : Ex Post Spreading Test (CMISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	23002	7.523	37.72*
ABN	221	5.039	1.43
AEGN	486	14.244	5.67*
AH	773	8.682	9.29*
AKZO	1957	3.320	6.35*
AMEV	429	17.256	7.69*
AMRO	1634	10.856	15.63*
BUHR	1112	10.590	10.41*
ELS	1352	5.981	9.65*
GB	1572	5.523	7.37*
HB	518	4.169	3.37*
HO	3860	7.543	14.29*
KLM	1014	11.752	10.59*
KNP	2776	5.842	12.44*
NED	2152	4.202	7.43*
NN	466	17.434	10.21*
PHIL	957	8.615	10.93*
RBC	434	7.827	8.49*
RD	480	14.240	7.80*
UNIL	809	3.786	5.31*

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-9 : Ex Post Spreading Test (AMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	22555	-1.159	-6.13
ABN	221	0.250	0.08
AEGN	473	3.613	2.31*
AH	757	-0.569	-0.82
AKZO	1932	-2.120	-4.70
AMEV	407	0.726	0.49
AMRO	1573	-3.273	-4.41
BUHR	1107	-4.191	-5.19
ELS	1292	1.602	2.63*
GB	1528	0.171	0.17
HB	513	3.810	3.01*
HO	3665	-3.442	-6.32
KLM	977	-1.118	-1.70
KNP	2720	-2.167	-4.62
NED	2271	1.944	2.02*
NN	446	-7.281	-3.74
PHIL	926	4.130	6.77*
RBC	416	-2.113	-1.94
RD	557	-5.589	-3.42
UNIL	774	0.565	0.91

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-10 : Ex Ante Spreading Test (AMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1337	-15.048	-15.78
ABN	21	-147.440	-4.14
AEGN	50	-13.959	-4.19
AH	48	-27.929	-4.01
AKZO	129	-5.263	-6.20
AMEV	22	-18.828	-3.01
AMRO	69	-25.213	-6.03
BUHR	27	-13.038	-3.20
ELS	59	-13.441	-5.54
GB	20	-13.455	-2.76
HB	91	-19.562	-9.01
HO	123	-9.045	-7.07
KLM	29	-8.796	-5.46
KNP	142	-6.509	-5.62
NED	152	-7.158	-5.07
NN	13	-13.960	-1.43
PHIL	44	-13.173	-5.16
RBC	69	-18.397	-4.66
RD	140	-15.927	-7.04
UNIL	89	-14.797	-5.97

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-11 : Ex Ante Spreading Test (AMISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1344	-10.223	-14.46
ABN	21	-109.244	-4.87
AEGN	50	-10.623	-3.46
AH	48	-19.398	-3.31
AKZO	131	-3.590	-6.59
AMEV	22	-16.467	-2.78
AMRO	69	-14.688	-5.28
BUHR	28	-11.309	-2.88
ELS	62	-9.823	-4.37
GB	20	-9.564	-2.65
HB	91	-15.037	-8.95
HO	124	-3.838	-4.36
KLM	29	-6.991	-4.17
KNP	142	-3.834	-4.69
NED	152	-6.122	-3.99
NN	13	-3.049	-3.35
PHIL	44	-5.968	-3.06
RBC	69	-12.140	-3.53
RD	140	-12.276	-6.81
UNIL	89	-7.195	-3.44

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-12 : _Ex_ _Post_ Spreading Test (AMISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	21895	7.446	27.18*
ABN	737	5.547	4.33*
AEGN	1406	7.496	6.19*
AH	1297	8.396	13.06*
AKZO	1515	-1.638	-3.31
AMEV	947	7.623	7.36*
AMRO	1157	4.802	10.58*
BUHR	1000	8.731	10.17*
ELS	1248	5.629	8.15*
GB	1309	11.667	15.69*
HB	811	6.008	8.34*
HO	2816	11.352	7.91*
KLM	1150	10.369	10.72*
KNP	2005	8.204	7.60*
NED	1294	3.223	2.98*
NN	1005	10.344	11.11*
PHIL	237	13.382	8.90*
RBC	427	4.576	3.88*
RD	1235	8.731	11.20*
UNIL	299	1.669	1.44

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-13 : Ex Post Spreading Test (AMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	21046	1.076	3.80*
ABN	728	1.545	1.68*
AEGN	1351	2.175	1.77*
AH	1256	4.491	5.22*
AKZO	1441	-1.283	-2.16
AMEV	901	-2.099	-2.12
AMRO	1097	0.534	1.11
BUHR	969	1.815	2.64*
ELS	1203	7.456	9.10*
GB	1268	0.328	0.42
HB	807	-0.163	-0.33
HO	2686	4.027	2.60*
KLM	1108	-1.901	-1.96
KNP	1911	2.277	2.59*
NED	1192	-5.208	-5.58
NN	965	-0.403	-0.60
PHIL	237	5.312	5.26*
RBC	419	0.314	0.30
RD	1208	-1.821	-2.85
UNIL	299	-1.881	-1.98

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-14 : *Ex Ante* Spreading Test (AMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1150	-23.210	-15.85
ABN	19	-114.879	-2.09
AEGN	17	-10.347	-3.17
AH	60	-24.174	-4.09
AKZO	174	-15.012	-10.00
AMEV	35	-38.717	-5.35
AMRO	39	-9.027	-4.68
BUHR	53	-17.706	-5.37
ELS	66	-30.129	-4.77
GB	50	-38.836	-3.71
HB	46	-9.348	-5.59
HO	97	-16.482	-6.48
KLM	9	-42.293	-3.04
KNP	90	-42.037	-7.91
NED	171	-14.106	-6.28
NN	30	-10.217	-4.31
PHIL	22	-33.844	-4.90
RBC	32	-8.042	-7.75
RD	78	-20.979	-3.99
UNIL	62	-34.600	-5.87

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-15 : *Ex Ante* Spreading Test (AMISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	1172	-18.108	-11.66
ABN	19	-118.205	-2.14
AEGN	17	-9.608	-2.91
AH	62	-22.429	-4.34
AKZO	175	-5.645	-3.47
AMEV	35	-25.748	-5.18
AMRO	39	-6.929	-4.73
BUHR	47	-12.085	-5.53
ELS	67	-21.493	-5.18
GB	53	-38.288	-2.89
HB	47	-7.520	-4.51
HO	98	-13.410	-5.91
KLM	10	-16.417	-2.62
KNP	91	-28.531	-6.58
NED	184	-18.085	-3.99
NN	30	-5.613	-5.56
PHIL	22	-17.795	-4.49
RBC	32	-7.500	-7.06
RD	82	-18.291	-3.10
UNIL	62	-18.875	-4.38

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-16 : Ex Post Spreading Test (AMISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

Option code	No. of Spreads	Average Rate of Return	t
All options	2384	2.578	11.68*
ABN	54	4.741	2.01*
AEGN	97	4.689	3.12*
AH	101	2.322	2.70*
AKZO	170	1.203	2.03*
AMEV	90	5.246	3.20*
AMRO	163	2.884	4.85*
BUHR	149	2.416	3.76*
ELS	172	3.048	3.36*
GB	181	3.681	3.01*
HB	75	1.401	1.68*
HO	286	1.445	3.09*
KLM	123	3.451	5.28*
KNP	223	1.402	2.99*
NED	166	2.172	2.20*
NN	76	4.829	3.61*
PHIL	47	-0.368	-0.32
RBC	61	2.916	2.86*
RD	61	3.782	1.73*
UNIL	89	1.458	2.16*

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-17 : _Ex Post_ Hedging Test (CMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2320	-0.441	-2.06
ABN	52	1.959	0.82
AEGN	97	0.656	0.39
AH	98	-0.188	-0.35
AKZO	164	-0.307	-0.61
AMEV	88	0.631	0.42
AMRO	159	-0.289	-0.58
BUHR	147	0.617	1.14
ELS	165	-1.914	-2.10
GB	176	0.148	0.14
HB	74	0.157	0.12
HO	274	-0.512	-1.03
KLM	121	-1.578	-2.17
KNP	217	-1.381	-1.78
NED	164	0.949	0.47
NN	76	-1.183	-0.95
PHIL	45	0.761	1.24
RBC	59	-0.584	-0.53
RD	61	-1.496	-1.06
UNIL	83	-3.427	-2.89

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-18 : Ex Ante Hedging Test (CMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	434	-1.898	-8.38
ABN	15	-5.634	-1.31
AEGN	23	-2.176	-1.80
AH	21	-3.037	-3.69
AKZO	29	-1.886	-3.12
AMEV	14	-0.874	-1.84
AMRO	29	-1.178	-2.92
BUHR	17	-1.830	-2.49
ELS	29	-2.289	-3.57
GB	22	-0.990	-1.63
HB	20	-0.874	-1.92
HO	34	-1.920	-3.97
KLM	13	-3.875	-3.93
KNP	32	-1.214	-2.32
NED	31	-1.551	-1.91
NN	17	-0.557	-0.62
PHIL	17	-2.139	-4.32
RBC	21	-1.633	-3.57
RD	24	-1.442	-2.49
UNIL	26	-2.700	-1.87

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-19 : Ex Post Hedging Test (CMISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2314	3.226	14.16*
ABN	56	2.280	3.64*
AEGN	152	3.528	2.99*
AH	123	4.321	4.41*
AKZO	145	1.673	2.11*
AMEV	121	3.939	4.61*
AMRO	120	2.074	3.32*
BUHR	103	1.699	2.16*
ELS	113	4.525	4.21*
GB	143	4.491	3.62*
HB	103	1.224	1.87*
HO	225	2.454	4.36*
KLM	146	3.646	5.64*
KNP	185	2.927	4.48*
NED	150	3.867	3.80*
NN	117	4.137	5.30*
PHIL	32	0.486	1.12
RBC	53	1.427	2.74*
RD	145	6.125	3.51*
UNIL	82	2.158	2.75*

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-20 : Ex Post Hedging Test (CMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2252	-0.158	-0.96
ABN	56	-0.610	-1.46
AEGN	145	-0.551	-0.67
AH	121	0.008	-0.06
AKZO	139	-1.425	-2.37
AMEV	118	-1.384	-1.61
AMRO	117	-0.496	-0.87
BUHR	102	0.407	0.32
ELS	112	2.620	1.46
GB	140	-0.086	-0.20
HB	101	0.844	0.87
HO	220	-0.864	-1.09
KLM	142	-0.453	-0.85
KNP	179	0.803	0.81
NED	143	1.953	1.65*
NN	112	-0.202	-0.37
PHIL	31	-0.555	-1.17
RBC	53	0.311	0.48
RD	143	-1.800	-2.09
UNIL	78	-1.531	-1.63

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-21 : _Ex_ _Ante_ Hedging Test (CMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	445	-2.901	-11.59
ABN	13	-3.013	-7.50
AEGN	21	-2.807	-3.30
AH	24	-2.730	-3.21
AKZO	40	-1.993	-4.11
AMEV	20	-2.199	-4.88
AMRO	24	-3.577	-3.45
BUHR	22	-2.504	-3.27
ELS	22	-3.050	-3.16
GB	18	-2.849	-5.50
HB	20	-1.889	-3.99
HO	37	-3.669	-3.75
KLM	15	-1.583	-2.98
KNP	26	-5.922	-2.00
NED	37	-1.560	-2.62
NN	16	-2.079	-3.43
PHIL	16	-2.398	-3.77
RBC	16	-3.722	-4.88
RD	30	-3.241	-5.21
UNIL	28	-3.819	-2.98

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-22 : Ex Ante Hedging Test (CMISD) with the Bid-Ask Spread Cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	450	-2.033	-12.57
ABN	13	-2.673	-6.43
AEGN	22	-2.413	-3.49
AH	24	-1.363	-3.63
AKZO	40	-1.639	-3.56
AMEV	20	-1.806	-4.05
AMRO	24	-2.204	-4.48
BUHR	23	-2.301	-3.31
ELS	22	-2.163	-3.05
GB	18	-2.145	-5.14
HB	20	-1.709	-3.84
HO	37	-2.431	-4.28
KLM	15	-1.285	-2.89
KNP	26	-2.249	-1.37
NED	38	-1.224	-2.55
NN	17	-1.804	-3.86
PHIL	16	-1.740	-3.29
RBC	16	-3.280	-4.60
RD	31	-2.093	-4.48
UNIL	28	-2.732	-2.77

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-23 : *Ex Post* Hedging Test (CMISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2925	2.398	10.51*
ABN	70	2.771	0.95
AEGN	95	3.565	2.16*
AH	110	2.874	1.99*
AKZO	207	1.531	3.30*
AMEV	95	7.421	3.09*
AMRO	197	2.222	2.31*
BUHR	149	3.821	3.39*
ELS	185	0.137	0.10
GB	212	1.621	2.69*
HB	90	1.572	1.12
HO	348	2.574	5.84*
KLM	155	2.279	3.10*
KNP	246	1.960	3.29*
NED	221	1.285	1.86*
NN	112	4.862	3.11*
PHIL	150	2.121	2.35*
RBC	67	5.230	3.74*
RD	91	3.219	1.94*
UNIL	125	0.846	1.27

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-24 : *Ex Post* Hedging Test (AMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2846	-0.671	-2.95
ABN	69	0.539	0.18
AEGN	93	0.905	0.82
AH	109	-0.415	-0.62
AKZO	202	-1.072	-2.67
AMEV	89	2.448	1.97*
AMRO	190	-0.987	-1.06
BUHR	144	0.131	0.07
ELS	177	-0.389	-0.55
GB	207	-0.482	-0.83
HB	89	0.929	0.50
HO	331	-1.171	-1.57
KLM	151	-0.357	-0.53
KNP	242	-1.406	-2.19
NED	220	-0.582	-0.42
NN	107	-2.235	-2.04
PHIL	145	-0.460	-1.05
RBC	65	-2.710	-1.04
RD	96	-2.163	-1.38
UNIL	120	-1.104	-1.54

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-25 : Ex Ante Hedging Test (AMISD)
16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	582	-4.963	-8.15
ABN	24	-15.439	-1.80
AEGN	31	-3.425	-3.04
AH	26	-4.456	-3.35
AKZO	33	-3.223	-3.66
AMEV	23	-9.684	-2.05
AMRO	41	-7.505	-2.51
BUHR	21	-1.398	-2.28
ELS	39	-6.062	-2.71
GB	20	-4.261	-1.79
HB	34	-9.969	-2.22
HO	52	-3.921	-4.56
KLM	24	-2.977	-3.58
KNP	35	-2.947	-1.64
NED	41	-3.871	-2.26
NN	20	-2.490	-4.24
PHIL	26	-2.209	-5.48
RBC	22	-2.017	-2.76
RD	42	-4.321	-2.22
UNIL	28	-3.537	-3.02

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-26 : Ex Ante Hedging Test (AMISD) with the Bid-Ask Spread Cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	586	-3.270	-6.93
ABN	25	-13.245	-1.99
AEGN	31	-3.824	-2.66
AH	26	-2.665	-3.86
AKZO	33	-1.513	-2.18
AMEV	24	-5.078	-1.85
AMRO	42	-3.011	-2.83
BUHR	21	-0.833	-2.46
ELS	39	-6.742	-2.05
GB	20	-3.809	-1.68
HB	34	-3.602	-2.09
HO	53	-2.441	-3.80
KLM	25	-2.298	-3.06
KNP	35	-2.016	-1.58
NED	41	-0.992	-0.74
NN	20	-1.850	-3.62
PHIL	26	-1.389	-3.51
RBC	22	-1.471	-2.03
RD	41	-4.821	-2.03
UNIL	28	-0.671	-1.27

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A2-27 : Ex Post Hedging Test (AMISD) with the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	3030	2.581	11.86*
ABN	146	1.817	2.56*
AEGN	213	2.914	2.26*
AH	166	5.616	5.08*
AKZO	174	2.003	3.10*
AMEV	156	3.436	3.73*
AMRO	165	1.093	1.64
BUHR	146	2.744	3.16*
ELS	172	2.356	4.05*
GB	176	2.273	2.75*
HB	128	0.517	0.79
HO	300	3.171	4.65*
KLM	183	4.274	3.90*
KNP	241	1.530	1.53
NED	149	1.973	2.51*
NN	155	3.616	4.93*
PHIL	58	1.121	2.60*
RBC	69	-0.639	-0.30
RD	162	3.186	4.06*
UNIL	71	2.419	2.61*

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-28 : Ex Post Hedging Test (AMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2931	0.318	1.08
ABN	145	-0.507	-0.72
AEGN	202	1.931	1.11
AH	162	1.728	1.59
AKZO	167	-1.047	-2.47
AMEV	149	-1.155	-1.47
AMRO	157	-0.173	-0.30
BUHR	142	0.819	1.05
ELS	166	2.941	2.04*
GB	170	0.365	0.38
HB	128	0.006	-0.06
HO	290	1.239	1.43
KLM	177	-1.397	-1.41
KNP	233	-0.463	-0.46
NED	140	2.514	2.12*
NN	149	-0.817	-1.43
PHIL	58	0.715	1.72*
RBC	68	1.667	1.35
RD	159	-2.310	-3.19
UNIL	69	0.277	0.16

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-29 : *Ex Ante* Hedging Test (AMISD)
4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	576	-4.092	-9.09
ABN	23	-4.598	-2.46
AEGN	29	-3.718	-2.37
AH	31	-4.023	-3.39
AKZO	52	-4.070	-3.45
AMEV	26	-9.847	-2.40
AMRO	27	-2.561	-4.34
BUHR	27	-5.078	-2.55
ELS	30	-1.544	-1.59
GB	31	-7.578	-2.25
HB	22	-2.352	-1.73
HO	49	-3.218	-3.43
KLM	14	-1.740	-2.23
KNP	48	-7.040	-3.17
NED	47	-0.519	-0.38
NN	22	-2.462	-3.06
PHIL	25	-4.465	-3.90
RBC	14	-3.061	-3.48
RD	29	-3.085	-1.95
UNIL	30	-5.648	-1.81

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-30 : *Ex Ante* Hedging Test (AMISD) with the Bid-Ask Spread Cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	585	-3.204	-7.49
ABN	23	-3.599	-2.46
AEGN	29	-3.461	-3.03
AH	32	-1.818	-2.17
AKZO	53	-1.344	-2.47
AMEV	26	-3.409	-2.53
AMRO	27	-1.802	-3.83
BUHR	28	-3.472	-3.50
ELS	31	-9.427	-1.88
GB	32	-6.668	-1.85
HB	22	-0.872	-2.87
HO	49	-2.919	-4.73
KLM	15	-0.979	-2.05
KNP	49	-5.826	-3.47
NED	48	-0.364	-0.47
NN	22	-1.834	-3.03
PHIL	25	-2.551	-3.05
RBC	14	-3.127	-3.09
RD	29	-1.111	-1.83
UNIL	31	-5.210	-1.80

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A2-31 : _Ex Post_ Hedging Test (AMISD) with the bid-ask spread cost 4 November 1988 to 15 December 1988

APPENDIX THREE

RESULTS OF EX POST TEST (DSISD) WITH

80 PER CENT OF THE BID-ASK SPREAD COST

Option Code	No. of Spreads	Average Rate of Return	t
All options	2129	-7.645	-22.18
ABN	46	-21.512	-5.31
AEGN	42	-5.739	-6.45
AH	133	-7.845	-7.19
AKZO	208	-4.010	-4.50
AMEV	47	-8.068	-7.30
AMRO	125	-4.764	-6.32
BUHR	101	-8.936	-9.05
ELS	107	-4.385	-6.71
GB	91	-3.304	-3.12
HB	154	-9.434	-9.93
HO	188	-3.597	-7.04
KLM	67	-3.883	-6.66
KNP	147	-2.822	-5.84
NED	209	-17.537	-15.99
NN	37	-10.938	-3.94
PHIL	60	-7.097	-3.85
RBC	90	-9.400	-6.96
RD	166	-8.920	-3.35
UNIL	111	-4.609	-3.44

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A3-1 : Ex Post Spreading Test (DSISD) with 80 per cent of the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	2053	-8.278	-22.64
ABN	54	-14.000	-6.06
AEGN	107	-9.001	-4.82
AH	93	-6.563	-5.83
AKZO	185	-3.898	-6.80
AMEV	105	-5.283	-4.28
AMRO	97	-4.806	-5.04
BUHR	75	-6.834	-6.91
ELS	164	-13.377	-7.13
GB	68	-3.745	-6.02
HB	98	-3.156	-4.65
HO	223	-11.888	-6.63
KLM	17	-3.498	-1.46
KNP	112	-7.698	-5.91
NED	318	-13.796	-13.00
NN	60	-6.158	-4.67
PHIL	47	-2.118	-1.77
RBC	79	-7.731	-8.10
RD	61	-1.048	-2.90
UNIL	90	-6.100	-5.13

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A3-2 : Ex Post Spreading Test (DSISD) with 80 per cent of the bid-ask spread cost 4 November 1988 to 15 December 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	578	-0.752	-1.72
ABN	21	2.078	0.98
AEGN	17	-0.987	-2.81
AH	29	-2.926	-2.52
AKZO	44	-0.535	-0.89
AMEV	20	-0.993	-1.84
AMRO	34	-0.739	-0.95
BUHR	29	-0.457	-0.66
ELS	29	-3.327	-3.52
GB	26	0.522	0.41
HB	47	-1.856	-3.13
HO	43	-1.991	-4.21
KLM	17	-1.307	-2.52
KNP	37	-1.098	-2.05
NED	46	5.858	1.78*
NN	16	-1.647	-2.37
PHIL	23	-0.173	-0.28
RBC	29	1.196	0.42
RD	42	-4.015	-0.93
UNIL	29	-2.815	-4.21

* Significant at 5%

Estimated risk-free interest rate = 5.5%

Table A3-3 : Ex Post Hedging Test (DSISD) with 80 per cent of the bid-ask spread cost 16 August 1988 to 27 September 1988

Option Code	No. of Spreads	Average Rate of Return	t
All options	611	-0.771	-3.14
ABN	23	-0.957	-0.93
AEGN	35	-2.761	-3.73
AH	29	-0.569	-1.89
AKZO	40	0.147	0.41
AMEV	29	-1.060	-2.89
AMRO	30	-1.825	-4.08
BUHR	24	-1.816	-3.65
ELS	46	-0.071	-0.25
GB	21	-0.881	-2.63
HB	26	-0.211	-0.61
HO	49	-1.664	-3.30
KLM	23	2.976	0.68
KNP	42	0.532	0.52
NED	67	-2.200	-1.69
NN	25	-1.031	-2.37
PHIL	23	2.125	1.26
RBC	24	-1.596	-1.42
RD	26	-1.353	-2.91
UNIL	29	0.097	0.05

* Significant at 5%

Estimated risk-free interest rate = 5.4%

Table A3-4 : <u>Ex</u> <u>Post</u> Hedging Test (DSISD)
with 80 per cent of the bid-ask spread cost
4 November 1988 to 15 December 1988

APPENDIX FOUR

VALUES OF SKEWNESS MEASURE

AND RESULTS OF SIGN TESTS

Option Code	(1)	(2)	(3)	(4)
All options	1.44	0.96	-6.03	-6.94
ABN	1.52	-0.86	-1.56	-1.94
AEGN	7.05	0.32	-1.04	-0.83
AH	1.94	-0.41	-4.56	-3.04
AKZO	0.97	0.05	-4.78	-5.99
AMEV	0.98	2.26	-0.66	-0.75
AMRO	2.54	0.10	-1.46	-3.52
BUHR	0.66	0.51	-2.80	-1.11
ELS	1.13	-0.73	-3.37	-3.47
GB	0.82	1.48	-2.85	3.19
HB	1.88	1.06	-2.28	-1.42
HO	0.12	0.22	-3.11	-1.72
KLM	0.84	3.88	-5.29	-2.85
KNP	1.93	-0.07	-2.82	-2.88
NED	0.05	-1.08	-0.55	-0.48
NN	-1.13	0.79	-3.30	-2.42
PHIL	-0.60	2.13	-3.92	-5.58
RBC	3.11	0.67	-2.56	-2.45
RD	-0.30	-3.72	-5.86	-5.92
UNIL	0.92	0.91	-2.40	-2.07

(1) Ex post test with zero transaction costs

(2) Ex ante test with zero transaction costs

(3) Ex ante test with the bid-ask spread cost

(4) Ex post test with the bid-ask spread cost

Table A4-1 : Values of Skewness
for Spreading Test (DSISD)
16 August 1988 to 27 September 1988

Option Code	(1)	(2)	(3)	(4)
All options	3.07	0.96	-4.39	-2.88
ABN	0.66	-1.64	-2.68	-1.91
AEGN	1.42	2.82	-3.67	-3.94
AH	3.01	1.96	-3.04	-3.53
AKZO	0.61	0.90	-3.73	-2.23
AMEV	1.97	-0.39	-3.33	-3.11
AMRO	1.03	1.46	-1.58	-3.85
BUHR	2.66	0.47	-2.05	-2.02
ELS	1.44	0.24	-3.07	-3.04
GB	1.13	-1.03	-1.33	-2.39
HB	0.09	3.13	-3.65	-1.30
HO	1.51	0.79	-1.20	-1.31
KLM	3.24	0.83	-0.40	-2.55
KNP	2.04	0.81	-1.54	-1.90
NED	1.22	0.77	-1.68	-1.30
NN	3.14	0.74	-2.67	-1.89
PHIL	0.79	0.38	-2.54	0.47
RBC	3.63	0.08	-2.99	-2.75
RD	1.61	-0.13	-2.69	-2.26
UNIL	0.97	1.73	-1.41	-1.67

(1) *Ex post* test with zero transaction costs

(2) *Ex ante* test with zero transaction costs

(3) *Ex ante* test with the bid-ask spread cost

(4) *Ex post* test with the bid-ask spread cost

Table A4-2 : Values of Skewness
for Spreading Test (DSISD)
4 November 1988 to 15 December 1988

Option Code	(1)	(2)	(3)	(4)
All options	8.07	16.21	2.07	-1.14
ABN	2.09	4.73	2.36	2.27
AEGN	5.71	-5.07	-1.12	-1.47
AH	3.09	-1.90	-3.98	-4.13
AKZO	6.65	-5.28	-2.28	-0.48
AMEV	4.66	2.17	-3.78	-3.10
AMRO	5.05	-0.16	-2.41	1.99
BUHR	3.78	0.46	-0.31	0.78
ELS	1.94	-3.20	-1.22	-1.82
GB	9.52	-2.75	-0.27	2.12
HB	5.70	-0.63	-5.09	-3.36
HO	2.14	0.62	-1.64	-1.36
KLM	5.80	-3.93	-1.44	-1.54
KNP	3.14	1.60	-2.63	-2.22
NED	5.30	-4.20	-2.54	2.79
NN	2.98	3.10	-1.29	-0.84
PHIL	2.21	0.87	-0.74	1.78
RBC	5.20	0.26	-5.08	4.06
RD	-1.22	4.12	4.31	-1.83
UNIL	2.07	-5.08	-3.29	-2.15

(1) *Ex post* test with zero transaction costs

(2) *Ex ante* test with zero transaction costs

(3) *Ex ante* test with the bid-ask spread cost

(4) *Ex post* test with the bid-ask spread cost

Table A4-3 : Values of Skewness
for Hedging Test (DSISD)
16 August 1988 to 27 September 1988

Option Code	(1)	(2)	(3)	(4)
All options	8.76	-3.00	-4.45	0.43
ABN	4.26	-2.92	-2.40	2.12
AEGN	5.43	4.12	-2.23	-1.72
AH	3.28	2.79	-1.17	-1.87
AKZO	6.68	-3.44	-5.38	0.84
AMEV	3.58	-4.24	-4.68	-3.13
AMRO	4.81	-1.91	-2.06	-2.01
BUHR	4.51	-1.75	-3.50	-2.48
ELS	3.63	-0.83	-3.58	-0.25
GB	2.06	-1.93	-2.00	-1.93
HB	3.47	5.33	3.33	1.64
HO	8.08	-4.29	-5.80	-1.93
KLM	7.23	-5.39	-3.07	4.37
KNP	-0.13	-1.49	-1.72	0.78
NED	6.76	-0.71	-3.31	-0.90
NN	3.42	-3.31	-3.19	-2.90
PHIL	4.16	-4.03	-2.78	3.68
RBC	5.50	-4.78	-3.35	-1.23
RD	6.12	-2.43	-4.71	-0.73
UNIL	2.44	-1.91	-3.77	2.83

(1) Ex post test with zero transaction costs

(2) Ex ante test with zero transaction costs

(3) Ex ante test with the bid-ask spread cost

(4) Ex post test with the bid-ask spread cost

Table A4-4 : Values of Skewness
for Hedging Test (DSISD)
4 November 1988 to 15 December 1988

Option Code	-----(1)------ Skewness	Z	------(2)------ Skewness	Z
All options	-6.31	-29.26	-2.56	-30.90
ABN	-1.85	-6.93	-1.93	-6.67
AEGN	-0.76	-3.55	-3.92	-7.54
AH	-3.22	-9.89	-3.53	-7.88
AKZO	-5.48	-4.78	-1.42	-8.82
AMEV	-0.80	-5.54	-2.81	-7.03
AMRO	-3.77	-7.51	-3.36	-4.67
BUHR	-0.74	-7.36	-1.94	-7.16
ELS	-3.05	-7.93	-3.03	-10.23
GB	4.83	-6.92	-2.28	-6.43
HB	-1.39	-8.46	-0.43	-4.75
HO	-1.72	-7.80	-1.00	-10.85
KLM	-2.68	-6.60	-2.08	-2.91
KNP	-2.80	-5.61	-1.45	-7.28
NED	-0.50	-11.07	-1.24	-13.74
NN	-2.33	-5.92	-1.90	-6.07
PHIL	-6.05	-7.36	1.01	-3.50
RBC	-2.70	-8.33	-2.45	-6.30
RD	-5.86	-4.58	-2.13	-1.28
UNIL	-1.72	-4.37	-1.66	-5.38

* Significant at 5%

Z is a standard normal variable

(1) 16 August 1988 to 27 September 1988

(2) 4 November 1988 to 15 December 1988

Table A4-5 : Values of Skewness and Results of SIGN Tests for <u>Ex Post</u> Spreading (DSISD) with 80 per cent of the bid-ask spread cost

Option Code	-----(1)------ Skewness	Z	------(2)------ Skewness	Z
All options	1.21	-8.11	5.73	-9.95
ABN	2.27	-0.87	2.97	-2.50
AEGN	-1.53	-2.91	-1.49	-2.70
AH	-4.22	-2.60	-0.97	-3.34
AKZO	1.17	-0.45	2.00	0.47
AMEV	-3.30	-1.57	-2.86	-2.97
AMRO	2.68	-2.92	-2.08	-3.10
BUHR	1.11	-1.11	-1.99	-3.88
ELS	-1.73	-2.60	0.94	-1.62
GB	2.28	-1.37	-0.79	-2.62
HB	-2.71	-3.50	2.08	-2.55
HO	-1.31	-3.66	-1.46	-3.14
KLM	-1.51	-2.43	4.68	-2.50
KNP	-1.53	-1.97	1.33	-1.08
NED	3.03	-1.03	0.08	-3.91
NN	-0.62	-2.25	-1.43	-2.80
PHIL	2.39	-2.09	3.68	-0.42
RBC	4.54	-3.71	0.42	-4.29
RD	-1.08	-0.15	1.00	-2.94
UNIL	-1.37	-2.23	3.42	-1.49

* Significant at 5%

Z is a standard normal variable

(1) 16 August 1988 to 27 September 1988
(2) 4 November 1988 to 15 December 1988

Table A4-6 : Values of Skewness and Results of SIGN Tests for *Ex Post* Hedging (DSISD) with 80 per cent of the bid-ask spread cost

Bibliography

Adam, N. and Peagam, N. "A Bullish Outlook for Amsterdam", in **Euromoney Supplement : Survey of the Amsterdam Stock Exchange**, May 1985

Beaver, W. H. "**Financial Reporting : An Accounting Revolution**", Prentice Hall, Inc., 1981

Beckers, S. "Standard Deviations Implied in Option Prices as Predictors of Future Stock Price Variability", **Journal of Banking and Finance**, 1981 pp363-381

Beckers, S. "On the Efficiency of the Gold Options Market", **Journal of Banking and Finance**, 1984 pp459-470

Bhattacharya, M. "Transactions Data Test of Efficiency of Chicago Board Options Exchange", **Journal of Financial Economics**, 1983 pp161-185

Black, F. "Fact and Fantasy in the Use of Options", **Financial Analysts Journal**, July-August 1975 pp36-72

Black, F. "How To Use The Holes In Black-Scholes", **Journal of Applied Corporate Finance**, Winter 1989 pp67-73

Black, F. and Scholes, M. "The Valuation of Option Contracts and a Test of Market Efficiency", **Journal of Finance**, 1972 pp399-417

Black, F. and Scholes, M. "The Pricing of Options and Corporate Liabilities", **Journal of Political Economy**, 1973 pp637-659

Blomeyer, E. C. and Klemkosky, R. C. "Tests of Market Efficiency for American Call Options", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath and Co., Lexington Books, 1983

Bookstaber, R. "Observed Option Mispricing and the Nonsimultaneity of Stock and Option Quotations", **Journal of Business**, 1981 pp141-155

Bookstaber, R. "**Option Pricing and Investment Strategies**", **Probus Publishing Co.**, 1987

Boyle, P. P. and Emanuel, D. "Discretely Adjusted Option Hedges", **Journal of Financial Economics**, 1980 pp259-282

Brenner, M. and Galai, D. "On Measuring the Risk of Common Stocks Implied by Options Prices : A Note", **Journal of Financial and Quantitative Analysis**, December 1984 pp403-412

Brenner, M. and Subrahmanyam, M. G. "A Simple Formula to Compute the Implied Standard Deviation", **Financial Analysts Journal**, September-October 1988 pp80-83

Castagna, A. D. and Matolcsy, Z. P. "A Two Stage Experimental Design to Test the Efficiency of the Markets for Traded Options and the Australian Evidence", **Journal of Banking and Finance**, 1982 pp521-532

Chiras, D. and Manaster, S. "The Information Content of Option Prices and a Test of Market Efficiency", **Journal of Financial Economics**, 1978 pp213-234

Choi, J., Salandro, D. and Shastri, K. "On the Estimation of Bid-Ask Spreads : Theory and Evidence", **Journal of Financial and Quantitative Analysis**, 1988 pp219-230

Cleeton, C. E. "**Strategies for the Options Trader**", John Wiley & Sons, Inc., 1979

Cox, J. and Rubinstein, M. "**Options Markets**", Prentice Hall, Inc., 1985

DATASTREAM **Traded Options Services Users' Manual**

Dorsman, A. B. and de Gooijer, J. G. "**On the Behaviour of Dutch Stock Market Prices and The Random Walk Hypothesis**", Paper presented to the International Symposium on Forecasting, Quebec City, Canada, May 1981

Dravid, A. R. "The Behaviour of Returns around Ex-dates for Splits and Stock Dividends", **Working Paper, Stanford University**, 1984

Dubofsky, D. and French, D. "More on the Increase in Volatility Subsequent to Stock Splits", **Working Paper, Texas A and M University and Texas Christian University**, 1985

European Options Exchange "**Trading Rules, April 1981**"

European Options Exchange "**Trading Regulations**"

European Options Exchange "**Annual Report 1988**"

European Options Exchange "**Annual Report 1989**"

European Options Exchange "**1978-1988 Report**"

European Options Exchange "**Explanatory Memorandum, 1988**"

European Options Exchange "**Contracts Specifications**"

European Options Exchange "**Stock Options, October 1987**"

European Options Exchange "**Minimum Commissions, 1988**"

Fama, E. F. "Efficient Capital Markets : A Review of Theory and Empirical Work", **Journal of Finance**, May 1970 pp383-423

Financial Times 20 June 1989

Financial Times 2 February 1990

French, D. W. and Henderson, G. V. "Substitute Hedged Option Portfolios : Theory and Evidence", **Journal of Financial Research**, Spring 1981 pp21-31

Galai, D. "**Pricing of Options and the Efficiency of the Chicago Board Options Exchange**", Unpublished Ph.D. dissertation, University of Chicago, 1975

Galai, D. "Tests of Market Efficiency of the Chicago Board Options Exchange", **Journal of Business**, 1977 pp167-197

Galai, D. "Empirical Tests of Boundary Conditions for CBOE Options", **Journal of Financial Economics**, 1978 pp187-211

Galai, D. "A Convexity Test for Traded Options", **Quarterly Review of Business and Economics**, 1979 pp83-90

Galai, D. "The Components of the Return from Hedging Options against Stocks", **Journal of Business**, 1983a pp45-54

Galai, D. "A Survey of Empirical Tests of Option Pricing Models", in **Option Pricing Theory and Applications**, Brenner, M. (ed.), D. C. Heath & Co., Lexington Books, 1983b

Gastineau, G. "**The Stock Options Manual**", McGraw-Hill Book Co 1975

Gastineau, G. "**The Options Manual**", McGraw-Hill Book Co, 1988

Gemmill, G. "The Forecasting Performance of Stock Options on the London Traded Options Market", **Journal of Business Finance and Accounting**, Winter 1986 pp535-546

Gemmill, G. and Dickins, P. "An Examination of the Efficiency of the London Traded Options Market", **Applied Economics**, 1986 pp995-1010

Gould, J. and Galai, D. "Transactions Costs and the Relationship Between Put and Call Prices", **Journal of Financial Economics**, 1974 pp105-129

Halpern, P. and Turnbull, S. "Empirical Tests of Boundary Conditions for Toronto Stock Exchange Options", **Journal of Finance**, 1985 pp481-500

Henkel, R. E. "**Tests of Significance**", Sage Publications, Inc., 1976

Hoaglin, D. C., Mosteller, F. and Tukey, J. W. "**Understanding Robust and Exploratory Data Analysis**", John Wiley & Sons, Inc., 1983

Hoel, P. G. "**Introduction to Mathematical Statistics**", John Wiley & Sons, Inc., 1971

Hull, J. "**Options, Futures, and Other Derivative Securities**", Prentice Hall International, 1989

Jarrow, R. and Rudd, A. "**Option Pricing**", Richard D. Irwin Inc, 1983

Jensen, M. C. "Some Anomalous Evidence regarding Market Efficiency", **Journal of Financial Economics**, 1978 pp95-101

Keane, S. "**Stock Market Efficiency**", Philip Allan Publishers Limited, 1983

Kemna, A. "An Empirical Test of the Option Pricing Model Based on Transactions Data of the European Options Exchange", Paper presented to the **European Finance Association Meeting**, 1987

Kerruish, A. "An Empirical Test of the Black-Scholes Option Pricing Model in the UK and Implications for Market Efficiency", Presented to the **European Finance Association Meeting**, September 1985

Klemkosky, R. C. and Resnick, B. G. "Put-call Parity and Market Efficiency", **Journal of Finance**, 1979 pp1141-1155

Klemkosky, R. C. and Resnick, B. G. "An Ex-Ante Analysis of Put-Call Parity", **Journal of Financial Economics**, 1980 pp363-378

Krausz, J. "Option Parameter Analysis and Market Efficiency Tests : A Simultaneous Solution Approach", **Applied Economics**, 1985 pp885-896

Latane, H. A. and Rendleman, R. J. "Standard Deviations of Stock Price Ratios Implied in Option Prices", **Journal of Finance**, 1976 pp369-381

Latane, H. A. and Rendleman, R. J. "Correction to 'Standard Deviation of Stock Price Ratios Implied in Option Prices', May 1976", **Journal of Finance**, 1979 pp1083

Leland, H. "Option Pricing and Replication with Transactions Costs", **Journal of Finance**, 1985 pp1283-1301

Lorie, J. H. and Hamilton, M. T. "**The Stock Market : Theories and Evidence**", Richard D. Irwin, Inc., 1973

Loudon, G. F. "Put Call Parity Theory : Evidence from the Big Australian", **Australian Journal of Management**, June 1988 pp53-67

Macbeth, J. D. and Merville, L. J. "An Empirical Examination of the Black-Scholes Call Option Pricing Model", **Journal of Finance**, 1979 pp1173-1186

Malkiel, B., and Quandt, R. "**Strategies and Rational Decisions in the Securities Options Market**", The MIT Press, 1969

Maloney, K. J. and Rogalski, R. "Call Option Pricing and the Turn of the Year", **Journal of Business**, 1989 pp539-552

Merton, R. C. "Theory of Rational Option Pricing", **Bell Journal of Economics and Management Science**, 1973a pp141-183

Merton, R. C. "The Relationship Between Put and Call Option Prices : Comment", **Journal of Finance**, 1973b pp183-184

Merton, R. C. "The Impact on Option Pricing of Specification Error in the Underlying Stock Price Returns", **Journal of Finance**, 1976 pp333-350

Ohlson, J. and Penman, S. "Volatility Increases Subsequent to Stock Splits : An Empirical Aberration", **Journal of Financial Economics**, 1985 pp251-266

Phillips, S. and Smith, C. "Trading Costs for Listed Options: The Implications for Market Efficiency", **Journal of Financial Economics**, 1980 pp179-201

Ritchken, P. "**Options : Theory, Strategy and Applications**", Scott, Foresman and Company, 1987

Rogalski, R. and Tinic, S. "The January Size Effect : Anomaly or Risk Mismeasurement ?", **Financial Analysts Journal**, November-December 1986 pp63-70

Roll, R. "An Analytic Valuation Formula for Unprotected American Call Options on Stocks With Known Dividends", **Journal of Financial Economics**, 1977 pp251-258

Roll, R. "A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market", **Journal of Finance**, 1984 pp1127-39

Rubinstein, M. "Nonparametric Tests of Alternative Option Pricing Models Using All Reported Trades and Quotes On The 30 Most Active CBOE Option Classes from August 23, 1976 through August 31, 1978", **Journal of Finance**, June 1985 pp455-480

Schmalensee, R. and Trippi, R. R. "Common Stock Volatility Expectations Implied by Option Premia", **Journal of Finance**, March 1978 pp129-147

Sheikh, A. M. "Stock Splits, Volatility Increases and Implied Volatilities", **Journal of Finance**, 1989 pp1361-1372

Solnik, B. H. "Note on the Validity of the Random Walk for European Stock Prices", **Journal of Finance**, December 1973 pp1151-59

Stuart, A. and Ord, J. K. "**Kendall's Advanced Theory of Statistics, Volume I : Distribution Theory**", Charles Griffin & Co Ltd, 1987

Swanson, J. E. "**The European Options Markets : A New Approach To Investment**", Kluwer Law and Taxation Publishers, 1984

Stoll, H. R. "The Relationship Between Put and Call Option Prices", **Journal of Finance**, 1969 pp 801-822

Stoll, H. R. "The Relationship Between Put and Call Option Prices : Reply", **Journal of Finance**, 1973 pp185-187

Trippi, R. "A Test of Option Market Efficiency Using a Random Walk Valuation Model", **Journal of Economics and Business**, 1977 pp93-98

Van der Hilst, J. "Marktefficiency op de EOE te Amsterdam", in **Financiering en Belegging**, stand van zaken anno 1980, Ballendux, F. J. (ed), Erasmus Universiteit, Rotterdam (1980)

West, R. R. "On the Difference Between Internal and External Market Efficiency", **Financial Analysts Journal**, November-December 1975 pp30-34