CONTRIBUTION N° 22

TRANSACTION COSTS ON THE LONDON TRADED OPTIONS MARKET AND A TEST OF MARKET EFFICIENCY BASED ON A PUT - CALL PARITY THEORY

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COUTS TRANSACTIONNELS SUR LE MARCHE DES OPTIONS DE LONDRES - UN TEST D'EFFICACITE DU MARCHE FONDE SUR LA THEORIE DE LA PARITE ACHAT - VENTE

100 COUTS TRANSACTIONNELS SUR LE MARCHÉ DES OPTIONS DE LONDRES - UN TEST D'EFFICACITÉ DU MARCHÉ FONDÉ SUR LA THÉORIE DE LA PARITÉ ACHAT-VENTE

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RESUME

Il est commode de scinder la théorie de la fixation du prix des options en deux volets : d'une part, les modèles d'équilibre général - tels que la théorie de la parité achat - vente avec des conditions limites d'options -, qui sont fondés sur la simple hypothèse que les investisseurs préfèrent gagner plus plutôt que gagner moins ; d'autre part les modèles d'évaluation, dont la validité repose sur des hypothèses distributives sur le cours du titre sous - jacent. Les deux types de modèles dérivent de l'hypothèse que les marchés des actions et des options sont sans viscosité et que le titre sous - jacent ne rapporte aucun dividende pendant la durée de vie de l'option. Des prouesses d'ingéniosité théorique ont été déployées pour tenter de réconcilier le monde réel - où les marchés présentent des viscosités et les actions donnent lieu au paiement de dividendes -, avec l'univers idéal de la théorie des prix des options. La présente Ctude, qui vise à combler la distance entre la théorie des prix des options, et la réalité empirique des marchés sur lesquels les prix des options sont fixés, a deux objectifs :

1 - Evaluer l'impact probable sur une stratégie d'opération fondée sur un modèle, des coûts transactionnels auxquels est confronté un opérateur sur le Marché des options de Londres, et determiner une méthode solide de prise en compte les coûts transactionnels dans cette stratégie.

2 - Tester l'efficacité du Marché des options de Londres en utilisant une théorie de la parité achat - vente, fondée sur les arguments d'arbitrage et donc exempte d'hypothèses sur la dynamique du titre sous - jacent.

La structure des coûts transactionnels sur le Marché des options de Londres est analysé et l'amplitude de l'écart entre l'offre et la demande sur les options, est étudiée en utilisant des évaluations en temps réel des prix au jour le jour sur ce marché. Des comparaisons sont faites entre la distribution des écarts entre l'offre et la demande sur le Marché des options de Londres et celle de la Bourse des options de Chicago, et une méthode améliorée pour tenir compte de l'écart entre l'offre et la demande des options dans des tests d'efficacité du marché est suggérée. Cette méthode de prise en compte des écarts entre l'offre et la demande est utilisée dans un test de l'efficacité du Marché des options de Londres, fondé sur une théorie de la parité achat - vente. Bien que de nombreux écarts à la parité offre - demande aient été constatés, très peu d'entre eux se sont avérés Ctre des occasions de profit exploitables, lorsque l'on tient compte des coûts transactionnels associés à la stratégie d'opération. L'efficacité du march4 ne peut donc pas Ctre niée, mais le grand nombre d'écarts à la parité achat - vente infirme l'hypothèse du synchronisme des marchés des actions et des options, sous - jacente aux modèles théoriques d'évaluation des options.

TRANSACTION COSTS ON THE LONDON TRADED OPTIONS MARKET AND A TEST OF MARKET EFFICIENCY BASED ON PUT-CALL PARITY THEORY

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Paper presented to the 1st AFIR International Colloquium, Paris, April 1989

Option pricing theory can conveniently be split into two groups - general equilibrium models, such as option boundary conditions and put-call parity theory which are based an the simple assumption that investors prefer more to less, and valuation models which rely for their validity on distributional assumptions about the underlying share price. Both types of model were derived on the assumption that the markets for shares and options are frictionless and that the underlying share pays no dividend during the life of the option. Much subsequent theoretical ingenuity has been employed in attempts to reconcile the real world of market frictions and dividend paying shares with the ideal world of option pricing theory. The current study, which attempts to bridge the gap between the theory of option prices and the empirical reality of markets in which option prices are set, has two aims :

1. To assess the likely impact on a model-based trading strategy, of the transaction costs facing a trader on the London Traded Options Market and to identify a robust method of accounting for transaction costs in the trading strategy.

2. To test the efficiency of the London Traded Options Market using put-call parity theory which is based on arbitrage arguments and is therefore free of assumptions about the dynamics of the underlying share.

The structure of transaction costs on the London Traded Options Market is analysed and the size of bid-ask spread on options is studied using real-time daily price quotations from the London Traded Options Market. Comparisons between the distribution of bid-ask spreads in London and that on the Chicago Board Options Exchange are made and an improved method of accounting for option bid-ask spread in market efficiency tests is suggested This method of dealing with bid-ask spreads is used in a test of the efficiency of the London Traded Options Market based on put-call parity theory. Although substantial numbers of deviations from put-call parity are identified, very few of these prove to be exploitable profit opportunities when transaction costs associated with the trading strategy are accounted for. Although market efficiency cannot therefore be rejected, the large number of deviations from put-call parity cast doubt on the assumption of synchronous share and options markets underlying theoretical option valuation models.

INTRODUCTION

The theory of option pricing can conveniently be split into two groups - general equilibrium models which are based on the simple assumption that investors prefer more to less, and valuation models which rely for their validity on distributional assumptions about the underlying share price. The former category includes boundary conditions on option prices {Merton (1973)}, and put-call parity theory which provides a relationship between the prices of puts, calls and the underlying securities {Stoll (1969), Klemkosky and Resnick (1979). Nisbet (1989)}. These general equilibrium relationships provide the context for the second group of models, principal among which is the call option valuation model derived by Black and Scholes (1973).

Both types of model were initially derived on the assumption that the markets for shares and options are frictionless and that the underlying share pays no dividend during the life of the option. Much subsequent theoretical ingenuity has been employed in attempts to reconcile the real world of market frictions and dividend paying shares with the ideal world of option pricing theory. The current study, which attempts to bridge the gap between the theory of option prices and the empirical reality of markets in which option prices are set, has two aims:

1. To assess the likely impact on a model-based trading strategy, of the transaction costs facing a trader on the London Traded Options Market and to identify a robust method of accounting for transaction costs in the trading strategy.

2. To employ this method in testing the efficiency of the London Traded Options Market using put-call parity theory. The trading strategy used is based on arbitrage arguments and is therefore free of assumptions about the dynamics of the underlying share.

Previous studies of the London Traded Options Market have been based on the Black-Scholes option pricing model. Both the pricing performance of the Black-Scholes model and the ability of the model to forecast share price volatility have been considered. {Kerruish (1985). Gemmill (1986) and Gemmill and Dickins (1986)). The current study therefore differs from previous studies both by explicitly considering the structure of transaction costs on the LTOM and by testing market efficiency using a test which is free of distributional assumptions about the underlying share price.

Section II of this paper presents the results of a study of the bid-ask spreads facing an arbitrageur on the London Traded Options Market and critically reviews previous methods'of accounting for bid-ask spreads in tests of market efficiency. Section III suggests an improved method of accounting far options bid-ask spread and reports the results of using this method in a test of the efficiency of the London Traded Options Market based on put-call parity theory. Section IV presents the conclusions of the paper.

SECTION II : BID-ASK SPREAD ON THE LONDON TRADED OPTIONS MARKET

2.1 Previous Research

An important friction in any options market is the bid-ask spread. The options price spread is the "round trip" costs of transferring cash into options and back again, and therefore represents a significant cost of transacting on the options market. Several theories of bid-ask spreads have been suggested.

Neal (1987) develops a model of option bid-ask spreads based on the theory of contestable markets which describes the spread as a function of volume of trading, option price and option volatility, with spread being positively correlated with option price and option volatility, and negatively correlated with volume of trading. Neal's model is broadly in agreement in its predictions with models of bid-ask spreads &rived by Stoll (1978). Ho and Stoll (1981), Copeland and Galai (1983) and Glosten and Milgrom (1985). The models by Stoll and Ho and Stoll are based on an examination of the optimal behaviour of a specialist and how this behaviour leads to bid-ask spreads. In particular their models predict that, since specialists require compensation for bearing risk, spreads should increase with price volatility. Studies by Benstron and Hagerman (1974) and by Branch and Freed (1978) find evidence of this type of relationship, but studies by Tinic (1972) and Tinic and West (1972) are inconclusive on this point. The spread models derived by Copeland and Galai and Glosten and Milgrom relate the spread to informational differences between market participants, with market makers setting the spread to offset losses to informed traders against profits from liquidity traders. The model derived predicts that since transaction prices are informative, spreads will tend to decline with volume.

Phillips and Smith (1980). in an empirical study of the bid-ask spread facing traders on the Chicago Board Options Exchange, estimate the cost of liquidity to effect options transactions by calculating the absolute and percentage spreads from observed bid and ask quotations in effect on the Chicago Board Options Exchange over four weeks in 1977/1978. Since there were restrictions on trading in options whose closing price was less than 50 cents, they report separately options whose prices are greater than 50 cents. Their results are presented in Table 2.1.

In the light of their analysis of transaction costs, Phillips and Smith reexamine the abnormal profits resulting from options trading strategies reported by Galai (1977, 1978), Trippi (1977). Chiras and Manaster (1978) and Klemkosky and Resnick (1979). Phillips and Smith argue that the most significant transaction cost facing a trader is the bid-ask spread and that the abnormal profits reported should therefore be reduced by the bid-ask spreads associated with the relevant trading strategy. They therefore use the mean of their observed spread distributions ($16.05 and 4.51 %) to reduce the profits reported 'in the above studies and this adjustment effectively eliminates all abnormal profits. It could however be argued that it is inappropriate to use a single figure to adjust abnormal profits, since the skewness and dispersion of the observed spread distributions reported in Table 2.1 make it unlikely that any single figure could be truly representative.

If for example a modal spread of $6.00, which on the basis of the information provided by Phillips and Smith looks like a reasonable estimate, is used as the basis of adjustment the abnormal profits reported by Galai (1977,1978) and Klemkosky and Resnick (1979) are not completely eliminated. Conclusions about market efficiency base on abnormal profits resulting from a trading strategy, are therefore sensitive to the assumption made about the appropriate level of spread. Phillips and Smith do not test for possible relationships between spread and the factors, such as price and volume of trading, identified in the theoretical models of bid-ask spreads as having a possible influence on spread

The main conclusion of Phillips and Smith is that transaction costs, and bid-ask spreads in particular, must be accounted for in any test of market efficiency involving trading rules. This conclusion remains valid. The method of adjustment for bid-ask spreads is however critical and whether a single average spread figure applied to abnormal profits can adequately account for the range of spreads observed ty Phillips and Smith remains questionable. The relevance of the Phillips and Smith study to empirical studies of the LTOM is dependent on whether or not similar spread distributions to those observed on the CBOE can be identified on the London market. Section 2.2. reports the results of a study of the bid-ask spread on the LTOM which attempts to answer this question.

2.2 Bid-Ask Spread on the LTOM

Prior evidence on the size of the bid-ask spread in the London market is largely anecdotal and both Gemmill (1986) and Kerruish (1985) refer to large bid-ask spreads without formally analysing them, A study was therefore carried out to analyse the spreads observed on the London market. This study was a prerequisite to further work on option pricing since if conclusions about market efficiency were to be obtained by simulating an arbitrageur's trading strategy, it is essential to understand the nature and size of transaction costs facing the trader on the market. The study reported below therefore provides the framework for the investigations of option market efficiency reported in Section III.

Real time option price quotations obtained by direct!feed from the floor of the London Traded Options Market were obtained from Datastream for a sample of twelve days during the period 27 June to 22 December 1988. All shares on which options were traded at the start of the sample period were observed which resuted on options on 53 companies being included in the sample. Bid and ask quotes for all options in all classes were obtained for each day in the sample. Two days from each calendar month were chosen and the sample was evenly spread, as far as possible, over days of the week. Table 2.2 gives the dates and corresponding days of the week for the sample and Table 2.3 reports the descriptive statistics for the call and option spreads observed. The spread distributions obtained for both calls and puts are given in Table 2.4.

Hypothesis tests were carried out to determine whether the sample percentage mean spread of the calls and puts in the British data were significantly different from those reported by Phillips and Smith for the "all options" data. The z values obtained are reported in Table 2.4 and it can be seen that the null hypothesis of no significant difference between the British and American spreads, is rejected in the case of the puts but is not rejected in the case of the calls at the 1 % level. It would therefore appear that the spreads on calls on the LTOM and the CBOE are similar. However, the medians of the two sets of distributions are different (Calls - LTOM 12.77 % and CBOE 4.23 % ; Puts - LTOM 15.38 % and CBOE 4.76 %) and the relative size of spreads on calls and puts in the two markets is reversed To investigate further the differences between the observations from the United States and those from the United Kingdom, Kolmogorov-Smirnov one sample and two sample tests were used. Table 2.5 reports the null and alternative hypotheses, the test statistics obtained and the critical values at a 1 % significance level for the Kolmogorov-Smirnov test.

On the basis of these tests, it must be concluded that the spread distributions reported in Phillips and Smith (1980) for the Chicago Board Options Exchange are significantly different from those reported in the current study and that the spreads on the LTOM an both puts and calls are larger than those reported by Phillips and Smith.

Having identified the distribution of bid-ask spreads on the London Traded Options Market, the question then arises of whether it is possible to identify any factors which can be associated with variability in spreads. When market makers on the LTOM were asked how they determined the size of the spread, they unanimously replied that they set the absolute spread in accordance with guidelines drawn up by the Stock Exchange. These guidelines relate the absolute size of the spread to the market price of the option and define the upper limit of the spread to be the size of the spread on the underlying security. *Prima facie,* a relationship between absolute spread and option price could therefore be expected. This relationship could take several forms, the simplest of which is linear of the form :

Absolute Spread = $a_1 + a_2$ Price where the a_i are constants.

The model was tested using simple linear regression, with absolute spread as the dependent variable and option mid-market price as the independent variable. Separate regressions were run on the call spreads and on the put spreads and on the calls and puts together. The results of the regressions are contained in Table 2.6. A significant relationship between the price of an option and the absolute bid-ask spread on the option can be seen to exist, with an R^2 value of approximately 0.5 and an F statistic with a significance level of less than 1 %. Therefore option price explains approximatively 50 % of the variability in the spread for both puts and calls. In addition, the t statistics obtained imply that both a_i terms in the regression are signficant and the model used therefore looks *prima facie* satisfactory.

It has been argued that, since option series which are far in-the-money or far out-the-money are less likely to be traded than series which are at- or near to-the-money, it is futile to examine prices of option series which are far in-the-money or far out-of-the-money and that spreads on at- or near-the-money options are likely to be more representative than deep in- or deep out-the-money options. [*Quality of Markets Quarterly* (1987)]. The regressions were therefore run again using only option series which had exercise prices within 10 % of the current share price. The results of these regressions are also reported in Table 2.6 and it can be seen that, as before, the relationship of price and spread is signficant and there is in fact an improvement in the explanatory power of option price on spread variability.

2.3 Implications for Tests of Market Efficiency

The results reported above have signficant implications for empirical investigations of options markets based on trading strategies. Two principal conclusions can be drawn:

I. The bid-ask spreads on both calls and puts observed on the London Traded Options Market are significantly larger than those reported by Phillips and Smith (1980) for the Chicago Board Options Exchange.

The conclusion of Phillips and Smith (1980) that transaction costs, and bid-ask spreads in particular, must be accounted for in any test of market efficiency based on trading rules is therefore also relevant to empirical studies of the LTOM.

II. On prices observed on the London Traded Options Market, there is a statistically significant relationship between bid-ask spread and option price.

This conclusion implies that the population of bid-ask spreads will change with changes in option prices. If, at a particular time, a sample distribution of bid-ask spreads is identified from the spread population, the moments of this distribution will reflect the price structure of the spreads contained in the sample. Therefore, it is unlikely that a moment of the sample spread distribution, for example the mean, will be a valid measure'of the corresponding moment obtained from a different sample with a different price structure. The spread adjustment made by Phillips and Smith involves applying the mean of the spread distribution obtained from their sample to abnormal profits derived from samples of options obtained by other researchers at different times. Although Phillips and Smith did not attempt to identify explanatory variables for option spread, Neal (1987) regresses option spread against *inter* alia option price and finds a statistically significant relationship. Therefore, because the price structures across samples would almost certainly vary, the sample spread distribution identified by Phillips and Smith is unlikely to be representative of the spread distributions faced by the researchers whose findings they examine. The validity of the method of adjustment for bid-ask spread used by Phillips and Smith must therefore be questioned on two grounds. Firstly, given the range of spreads observed, it is unlikely that a single figure used for spread adjustment could adequately represent the range of spreads faced by a trader on the markets. Secondly, even if it were possible to fine tune the adjustment to reflect the variability in spreads, it is highly unlikely that Phillips and Smith's sample spread distribution could provide a legitimate basis for adjustment in all cases since the price structure of the Phillips and Smith sample is unlikely to be universal. Section III reports the results of a test of market efficiency which suggests and uses an alternative method of allowing for bid-ask spread in the trading strategy.

SECTION III : EMPIRICAL TESTS OF PUT-CALL PARITY ON THE LTOM

3.1 The Theory of Put-Call Parity

Klemkosky and Resnick (1979) derive the following versions of the put-call parity theorem which allow for a finite number of known dividends, d_i, being paid on the underlying share at time t_i.

$$C_t - P_t - S_t + [K + \Sigma_1^n d_j(1+r)^{\delta_j}]/(1+r) \leq 0 \ldots\ldots (3.1)$$

and

$$P_t - C_t + S_t - [K + \Sigma_1^n d_j(1+r)^{\delta_j}]/(1+r) \leq 0 \ldots\ldots (3.2)$$

where

K	=	exercise price
C_t	=	call price at time t
P_t	=	put price at time t
S_t	=	share price at time t
t	=	current time
T	=	date of maturity of option (expiry date)
r	=	interest rate over interval $[t,T]$
$B(t,T-t)$	=	the price of a riskless bond at time t which pays £1 at time T.
n	=	number of dividends paid on share over option period.
t_i	=	ex-dividend date for i'th dividend
d_i	=	certain dividend paid at t_i
τ	=	time to maturity of option (T–t)
δ_i	=	the fraction of the option period remaining after the payment of dividend i

Inequality 3.1 is derived by considering the cash flows associated with a long hedge position consisting of buying a share, writing a call, buying a put with the same expiry date and exercise price as the call and borrowing an amount which requires to be repaid on the expiry date by an amount equal to the exercise price. Inequality 3.2 is derived by considering the cash flows associated with a short hedge consisting of writing a put, buying a call, shorting the underlying share and lending an amount which will result in being repaid the exercise price on the expiry date. These inequalities depend for their validity on the assumptions that the arbitrageur is not vulnerable to early exercise of the call in the long hedge nor of the put in the short hedge. Klemkosky and Resnick derive the condition for no early exercise of the call in the long hedge (inequality 3.3) and for no rational premature exercise of the put in the short hedge (inequality 3.4).

$$\Sigma_1^n d_j(1+r)^{1-\delta_j} < iK/(1+r) \ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

$$C_t > [iK - \Sigma_1^n d_j(1+r)^{\delta_j}]/(1+r) \ldots\ldots\ldots\ldots\ldots (3.4)$$

Nisbet (1989) extends Klemkosky and Resnick's analysis to take account of transaction costs and derives the following modifications to (3.1) and (3.2).

$$C_t - S_t - P_t + K/(1+r) - T_C - T_S^t - T_P - 2T_S^T/(1+r) + \Sigma_1^n d_j(1+r)^{\delta_j}/(1+r) \leq 0 \quad \ldots(3.5)$$

$$P_t - C_t + S_t - K/(1+r) - T_C - T_S^t - T_P - 2T_S^T/(1+r) - \Sigma_1^n d_j(1+r)^{\delta_j}/(1+r) \leq 0 \quad \ldots(3.6)$$

where

T_C = the costs of the call transaction
T_S^t = the costs of the share transaction at time t
T_P = the costs of the put transaction
T_S^T = the costs of the share transaction at time T.

In addition, Nisbet modifies (3.3) and (3.4) to provide the following conditions, in the presence of transaction costs, for no early exercise of the put in the long and short hedges respectively.

$$iK/(1+r) > \Sigma_1^n d_j(1+r)^{\delta_j}/(1+r) - 2T_C - 2T_S^t - T_P - 2T_S^T/(1+r) \ldots\ldots\ldots\ldots(3.7)$$

$$C_t > iK/(1+r) - T_C - 2T_S^t - 2T_P - 2T_S^T/(1+r) - \Sigma_1^n d_j(1+r)^{\delta_j}/(1+r) \ldots\ldots\ldots\ldots(3.8)$$

3.2 Data

The data used in the study were real time option price quotations with synchronous share prices obtained by direct feed from the floor of the London Traded Options Market. Both bid and ask option prices were available and it was therefore possible to explicity account for bid-ask spread in each hedge by using the bid (ask) price when an option was written (bought). Daily option price quotations and prices for the underlying shares were obtained from Datastream for the period 27 June to 22 December 1988. All shares on which options were traded at the start of the sample period were observed ; consequently options on 53 companies were included in the sample. Since options traded on the LTOM are not dividend payout protected it was necessary to include dividend payments in the model tested. Expected dividend dates and rates were therefore obtained from Datastream fur each company included in the sample.

The risk-free rate was estimated by the Inter Bank Rate (IBR) over the relevant period. In an attempt closely to match the interest rate structure facing an arbitrageur, annualised bid and ask rates for one, three, six and twelve months were obtained for each day in the sample period. The interest rate used for each hedge was therefore the annualised bid or ask rate (depending on whether the hedge required borrowing or lending) most closely matched to the period to expiry of the options in the hedge. To obtain an interest rate over the life of the hedge, the annualised rate was prorated to the number of days to expiry of the option, on the assumption that, once borrowing or lending had taken place at that rate, the rate was fixed over the option period

3.3 Methodology

The current study employs the standard &vice of establishing hedge portfolios which in equilibrium should return the risk-free rate. Any hedges which return more than the risk-free rate therefore provide a profit opportunity. However the current methodology differs from previous tests of put-call parity in two substantive ways - firstly in the treatment of transaction costs and secondly in testing f a premature termination of the short hedge.

Each day hedges were created for every call price quotation for which there was a corresponding put price quotation, where "corresponding" means that the put is written on the same share and has the same expiration date and exercise price as the call. Any call or put which had a bid or ask price equal to zero was excluded since any such price was necessarily spurious. Over the six months period 27.263 *call* prices were considered and the hedges created were tested using each of the tests described below. Because of the marginal profits involved in many of the hedges, for each company only the most profitable hedge in any day was used.

Hedges were first created using the relationships between the prices of the call, put, share and exercise price given by (3.1) and (3.2) above. The left hand sides of expressions (3.1) and (3.2) represent the costs of setting up a long and short hedge respectively If arbitrage is to be avoided and if the hedge position is not to be prematurely terminated by the early exercise of the written call or put, then the upper bound for both expression (3.1) and (3.2) must be zero. If significant numbers of violations of these boundaries are found, put-call parity theory would be rejected and the efficiency of 'the market would be in doubt.

The mid-market prices of both calls and puts were first used as option price inputs to this model and no account was therefore taken of any transaction costs in these tests, subsequently referred to as tests of Model I, and correspond to the tests carried out by Klemkosky and Resnick (1979) which ignore transaction costs in the model tested.

As explained in Section II, transaction costs have been accounted for in previous tests of put-call parity, not by taking explicit account of transaction costs in the model tested but by identifying a single "reasonable*' round trip cost and applying it to all apparently profitable hedges. As has been discussed above, bid-ask spreads show considerable variability and in addition commission rates in the London market are sensitive to the size of the individual transaction. Therefore, tests which apply a flat rate transaction cost to all hedges do not adequately capture the impact of transaction cost variability. In the London Traded Options Market, where both the level and variability of transaction costs are higher than those observed in United States markets, the impact of transaction costs is likely to be even more significant.

In an attempt to isolate the effects of the different elements of transaction costs faced by an arbitrageur, three further models were tested. Model II tests differ from Model I tests only in that they apply option bid price for the written option and the option ask price for the purchased option in the creation of the hedges implied by inequalities (3.1) and (3.2). For example, in the long hedge the call option bid price and put option ask price were used. Model 11 tests therefore account for the transaction costs associated with option bid-ask spreads, although no account is taken of commission on options, or of transaction costs associated with the share transactions.

Under Models I and II, any hedge which was prima facie profitable was tested for susceptibility to early exercise using inequality **(3.3)** for the long hedge and inequality **(3.4)** for the short hedge. A short hedge could satisfy inequality **(3.4)** at inception but still violate it before the expiration date of the options. No short hedge is therefore truly risk-free. To obtain an insight into the scale of this problem, condition **(3.4)** was retested each day during the life of each profitable short hedge under both Model I and 11 and any hedge which violated the condition, and which was therefore vulnerable to early termination, was excluded from the set of profitable hedges. This test, while obviously having no predictive relevance to an arbitrageur, does provide an insight into the scale of the early exercise risk associated with the short hedge portfolio.

It can validly be argued that using option price quotations in the model does not allow actual profit opportunities to be identified, since the price relationships within which profit opportunities can be identified are likely to be materially different from the prices prevailing at the time transactions actually take place. In an attempt to overcome this problem, *ex-ante* tests were carried out. Any hedge identified as providing a profit opportunity was reestablished one day later using prices then prevailing, and was tested both to determine whether or not the hedge had remained profitable and whether it had become vulnerable to early exercise over the intervening period.

To take account of remaining transaction costs associated with the hedge strategy, the tests described above were repeated using expressions **(3.5)** and **(3.6)**. The transaction cost terms in expressions **(3.5)** and **(3.6)** derive both from commission charges and bid-ask spreads. As can be seen from Tables **3.1** and **3.2,** the level of commission charged on an option transaction depends on the number of contracts included in the bargain and consequently on the value of the transaction, and the share commission rate depends on the total value of the equity transaction. In an attempt to isolate the effects on commission costs of different transaction sizes, three different levels of option and share commission rates were applied to each hedge. These were classified as High, Medium and Low and the following commission rates were used:

Level of Costs	Option Commission	Share Commission
High	6.06%	5.69%
Medium	3.36%	0.86%
Low	0.54%	0.20%

For the underlying shares, however, only the mid-market prices, and not the bid and ask quotations were available. Shares are classified on the London International Stock Exchange into Alpha, Beta, Gamma and Delta shares according to how actively they are traded. Alpha share are the most heavily traded and all shares in which options are traded are Alpha shares. At the end of September 1988, the average touch (the difference between the highest bid price and the lowest ask price over all market makers) for Alpha stocks was 0.80 % and the average spread was 1.45 %. (Quality of Markets Quarterly (Autumn 1988), page 11). To estimate conservatively the spread on shares the higher of these two figures was used and 0.725 % was therefore obtained and applied to the appropriate share price in each hedge.

All transaction costs are identifiable at the time the hedge is established excepts T_S^T, the closing share commission. No hedge created from expressions (2.5) and (2.6) is therefore truly riskless, unless an upper bound can be placed on T_S^T. Given the structure of transaction costs facing a trader in the London market and the fact that T_S^T is a function of closing share price, it is not possible to place an upper bound on T_S^T. In an attempt to assess the impact of the closing transaction costs on the number of profit opportunities, each test was therefore run using two different assumptions. Firstly hedges which allowed for opening transaction costs only were created and tested for profitability using each of the three levels of transaction costs. These are referred to as Model III tests. These tests were then repeated by creating hedges which allowed both for the opening and closing transaction costs. Difficulty is of course encountered in assessing the appropriate level of closing transaction costs. However, if it is assumed that the share price follows a random walk, then the best estimate of the share price at T, *the* expiration date of the options in the hedge, is the current share price. The commission and spread relevant to the current share price was therefore used as a surrogate for the closing share transaction costs. These tests are referred to as Model IV tests.

Each profitable hedge identified using Models III and IV was then tested for susceptibility to early exercise by using inequalities (3.7) and (3.8) for long hedges and short hedges respectively. For consistency, hedges which were profitable if closing transaction costs were ignored, were tested using expressions (3.7) and (3.8) with closing transaction costs omitted, and hedges which were profitable after full account was taken of transaction costs were tested using the unamended versions of (3.7) and (3.8). Since transaction costs make early exercise less likely, inequalities (3.7) and (3.8) provide a less stringent test for vulnerability to early exercise than inequalities (3.3) and (3.4).

All hedges which were potentially profitable ex-post and were not susceptible to early exercise, were then subjected to the *ex-ante* test described above.

3.5 Results and Interpretation of Put Call Parity Tests

A total of 27,263 call prices were used in creating the hedges for each of Model I and Model II. Each hedge was tested for profitability and vulnerability to premature exercise. Table 3.3 contains a summary of the number of ex-post profitable hedges identified. Consistent with theory and the findings of Klemkosky and Resnick, under both Models there are larger numbers of profitable short hedges than profitable long hedges identified, because of the risk associated with early exercise in *the short* hedge. Table 3.3. also contains the results of the *ex-ante* test and it can be seen that even when the *ex-ante* test is applied to ex-pos&profitable hedges, substantial numbers of Models I and II profit opportunities remain, indicating prima *facie* violations of put-call parity and exploitable inefficiencies in the market. Two aspects of the Models I and II results are interesting. Firstly the effect of accounting for the bid-ask spread in the Model II tests is to reduce by half the total number of ex-ante and ex-post profitable hedges. This supports Phillips and Smith (1980) in their conclusion that it is essential to account for the bid-ask spread in any empirical study of market efficiency. Secondly, the suprisingly large number of profitable hedges identified prima facie contradicts put-call parity theory and casts doubt on the validity of its assumptions. In particular, the results suggest either the efficiency of the LTOM or the equilibrium between the option and share markets must be questioned.

Since it is possible at inception to test whether or not the long hedges are susceptible to premature termination, long hedges represent true arbitrage opportunities under Models I and II. Because short hedges may be vulnerable to premature exercise, they are not truly risk-free. Table 3.4 contains, f a both Models I and II the results of testing the short hedges which were ex-post profitable for violation of condition (3.4) over the life of the options in the hedge. Under both models, there is a substantial reduction in the number of hedges which remain viable after this test and when these remaining hedges are tested for *ex-ante* profitability there is a further drop in the number which would have provided a profit opportunity. Consistent with expectations since the Model I call price is higher, a larger proportion of Model II hedges failed to provide a profit opportunity. These results indicate that there is a significant probability of premature exercise of the short hedged portfolio and the short hedge in either Model I or Model II cannot therefae be regarded as risk-free. 'Even the ex-ante short hedge "profit opportunities" in Table 3.3 must therefore be regarded with some skepticism.

Table 3.5 shows for both long and short conversions, the numbers of *ex-post* and ex-ante Model III profitable hedges (i.e. hedges which remain profitable when the costs of establishing the hedge are reduced from the Model II hedge "profit"). Results are presented for each of the three levels of transaction costs identified above. Consistent with expectations, there is a sustantial drop in the numbers of ex-post and ex-ante profitable hedges when the costs of setting up the hedge are accounted for. In addition, the number of hedges which remain profitable after setting-up costs, depends critically on the assumption ma& about the appropriate level of transaction costs and therefore on the size of the transaction.

When the Model IV profitable hedges are identified by deducting an estimate for the closing share price transaction as described in the Methodology section, from the remaining Model III profit, there is a further substantial reduction in the number of profitable hedges for all levels of transaction costs. Table 3.5 summarises the Model IV findings and again it can be seen that the number of arbitrage opportunities remaining after all transaction costs are accounted for depends critically on the assumption made about level of transaction costs.

When interpreting Table 3.5, it must be bome in mind that the "profit opportunities" identified are based on hedges which are not truly risk-free since they are subject to error in the estimate of the closing share transaction costs used. One is therefore drawn to the conclusion that although the Model I and II tests implied large numbers of deviations from put-call parity, these did not represent exploitable inefficiencies in the market because of the impact of transaction costs. Even an arbitrageur trading in very large amounts (over £1 million per transaction) and paying consequently very low rates of commission, could only have identified 394 ex-ante profit opportunities out of over 27,000 studied.

SECTION IV : CONCLUSIONS

This paper has presented the results of an empirical test of the bid-ask spreads on the London Traded Options Market and, based on the results of that study, has tested the efficiency of that market. Four models were tested corresponding to different assumptions about the appropriate level of transaction costs facing an arbitrageur in the LTOM.

The empirical results of the Model II test (which ignored transaction costs other than bid-ask spread on the options) suggested that there were significant numbers of deviations from put-call parity in prices quoted on the London Traded Options Market. A large number of the potentially profitable short conversions became susceptible to early termination during their lives and, reflecting this increased risk, a greater number of short hedge than long hedge violations were identified. The Model III and IV test results (which measured hedge profitability after all opening transaction costs and all transaction costs respectively) indicate that these violations of put-call parity are unlikely to represent exploitable inefficiencies in the market.

Previous studies of put-call parity in the U.S. have not taken specific account of transaction costs in the model tested, but have deducted a single round trip transaction cost to emulate the effect of transaction costs on the hedge profit. The current study has demonstrated that it is possible to account for transaction costs in the put-call parity model. Not so to do may result in the identification of spurious profit opportunities.

The current study also has implications for research employing option pricing models. The evidence presented in this paper can be interpreted in one of two ways. Either it suggests that the equity and options markets are not synchronous or that there are inefficiencies (which may not be exploitable after transaction costs) in the prices quoted on the LTOM. If market synchronisation and/or efficiency is rejected based on testing put-call parity, it must also be rejected when a pricing model is used on the same data base. The current study therefore provides a context for future research into the pricing structure of the London Traded Options Market.

Table 2 1 : Distributions of Average Spreads Per Contract Reported by Phillips and Smith (1980)

	CALLS		PUTS	
% Spreads	All	> 50c.	All	> 50c.
0.0 - 0.2	7	5	7	5
0.2 - 0.4	0	0	0	0
0.4 - 0.6	7	7	3	3
0.6 - 0.8	6	6	0	0
0.8 - 1.0	16	16	3	3
1.0 - 1.2	13	13	6	6
1.2 - 1.5	50	50	6	6
1.5 - 2.0	49	49	19	15
2.0 - 3.0	166	163	109	105
3.0 - 5.0	188	181	181	161
5.0 - 8.0	116	112	132	127
8.0 - 12.0	55	49	70	66
12.0 - 20.0	35	13	44	23
20.0 - 30.0.	17	1	11	3
30.0 - 50.0	32	3	9	0
50.0 - 100.0	21	2	6	3
> 100.0	98	0	26	0
n	876	670	632	526
mean (%)	29.85	4.51	15.00	5.77
median (%)	4.23	3.39	4.76	4.44

	CALLS		PUTS	
$ Spreads	All	> 50c.	All	> 50c.
0.00 - 6.25	311	145	169	145
6.25 - 12.50	252	225	220	1%
12.50-25.00	215	213	143	136
25.00-50.00	90	79	83	59
> 50.00	8	8	17	17
mean ($)	16.05	18.23	18.84	19.10
median ($)	12.50	12.50	12.50	12.50

Bble 2 3 : Days Included in Sample of Bid-Ask Quotations

Monday	Tuesday	Wednesday	Thursday	Friday
18 July	16 August	28 September	7 October	25 November
14 November	11 October	24 August	6 September	16 December
	20 December		14 July	

Table 2 3 : Distributions of Average Spreads Per Contract on the LTOM

% Spreads	CALLS	PUTS
0.0 - 0.2	0	0
0.2 - 0.4	1	0
0.4 - 0.6	4	0
0.6 - 0.8	3	0
0.9 - 1.0	8	1
1.0 - 1.2	72	26
1.2 - 1.5	0	0
1.5 - 2.0	0	0
2.0 - 3.0	183	97
3.0 - 5.0	680	432
5.0 - 8.0	1397	816
8.0 - 12.0	1753	1385
12.0 - 20.0	1729	1697
20.0 - 30.0	1019	1278
30.0 - 50.0	643	919
50.0 - 100.0	501	837
> 100.0	706	1179
n	8699	8667
mean (%)	29.76	42.69
median (%)	12.77	19.23
standard deviation (%)	46.74	56.59

Table 2 4 : Descriptive Statistics of **Percenage** Spread Distributions

	Mean	Standard Deviation	Number of Observations
All option	**36.22**	**52.29**	**17366**
Calls	**29.76** **(z^* = 0.18)**	**46.74**	**8699**
Puts	**42.69** (z^* = 45.56)	56.59	**8667**

z^* is the test statistic from a hypothesis test based on a **comparison** of **the** sample mean obtained in the current study with the "all options" mean reported by Phillips and Smith **(1980).**

Table 2 5 : Comparison of CBOE and **LTOM Spreads-Komogorov-Smirnov** Tests

Kolmogorov-Smirnov Two Sample Test

H_0 : The population distributions of **percentage** bid-ask spreads on the **LTOM** and **the** CBOE from which the **samples** of calls **(puts) were** drawn are not **significantly** different.

H_1 : There is a significant difference between the two distributions.

	Calls	Puts
Test Statistic	**0.464**	**0.579**
Critical value (1 %)	0.043	**0.050**
Accept/Reject H_0	Reject	Reject

Kolmogorov-Smirnov One Sample Test

H_0 : **The** population distribution **of** percentage **bid-ask** spreads on calls **(puts)** on the CBOE is not stochastically larger than the population distribution of **percentage** bid-ask **spreads** on calls **(puts)** on the **LTOM.**

H_1 : There is a **significant diffrence** between the two distributions.

	Calls	Puts
Test Statistic	**1476.2**	**1364.3**
Critical value (1 %)	**9.2**	**9.2**
Accept/Reject HO	Reject	**Reject**

Table 2.6 : Simple Linear Regression of Absolute Spreads against Option Price

	R^2	F (sig level)	Variable	Regression Parameters a_i	Std erm	t (sig level)
Entire Sample						
Calls & Puts	0.509	17976 (0.00)	Price	0.04	0.0003	134.08 (0.00)
(n = 17366)			Constant	1.89	0.0153	124.19 (0.00)
Calls	0521	9477 (0.00)	Price	0.04	0.0004	97.35 (0.00)
(n = 8699)			Constant	1.87	0.0232	80.80 (0.00)
Puts	0.500	8514 (0.00)	Rice	0.04	0.0005	92.27 (0.00)
(n = 8667)			Constant	1.87	0.0200	93.38 (0.00)
Near-the-money	R^2	F (sig level)	Variable	Regression Parameters a_i	Std error	t (sig level)
Calls & Puts	0.601	14168 (0.00)	Price	0.07	0.0006	119.03 (0.00)
(n = 9397)			Constant	158	0.0199	79.61 (0.00)
Calls	0.610	7348 (0.00)	Price	0.07	0.0008	85.72 (0.00)
(n = 4703)			Constant	1.48	0.0300	50.10 (0.00)
Puts	0.624	7802 (0.00)	Ria	0.08	0.0009	88.34 (0.00)
(n = 4694)			Constant	156	0.0261	60.23 (0.00)

Note

The significance levels of h e F and t statistics are contained in parenthesis after the values of the test statistics.

Table 3.1 : Commission Rates on UK Equities - July 1988

Bargain Size (£)	Average Commission Rate (%)
0 - 600	5.69
601 - 2000	2.00
2001 - 10000	1.46
10001 - 20000	0.86
20001 - 50000	0.47
50001 - 100000	0.31
100001 - 250000	0.25
2500001 - 1 million	0.23
over 1 million	0.20

Source : *Quality of Markets Quarterly*, 1988

Table 3.2 : Commission Rates on UK Traded Options - July 1988

Bargain Size (Contracts)	Average Commission Rate (%)
1	6.06
2	2.71
3	3.08
4	2.31
5	2.59
6 - 10	3.36
11 - 50	1.33
51 - 100	1.03
over 101	0.54

Source : *Quality of Marlets Quarterly*, 1988

Bble 33 : Numbers of *Ex-Post* and *Ex-Ante* Profitable Hedges From Model I Test

	Model I		Model II	
Hedge Profitable	*ex-post*	*ex-ante*	*ex-post*	*ex-ante*
Long Hedges	3602	1729	1090	591
Short Hedges	5477	4789	3093	1955
Total	9079	6518	4183	2546

Bble 3.4 : Numbers of *Ex-Post* Profitable Short Hedges Not Violating Condition for No Early Exercise Before Option Expiration

	Model I	Model II
Ex-post profitable short hedges from Table 3.3	5477	3093
Number of ex-post short hedges not violating condition	2235	1012
Number of hedges not violating condition which are profitable ex-ante	1910	478

Table 35 : Numbers of *Ex-Post* and *Ex-Ante* Profitable Hedges From Model III and Model IV Tests

Hedge Profitable	MODEL III *ex-post*	MODEL III ex-ante	MODEL IV ex-post	MODEL IV *ex-ante*
High Transaction costs				
Long Hedge	63	34	40	15
Short Hedge	70	63	20	18
Total	133	97	60	33
Medium Transaction costs				
Long Hedge	235	152	114	60
Short Hedge	819	613	116	99
Total	1054	765	230	159
Low Transaction costs				
Long Hedge	383	205	196	123
Short Hedge	1492	960	423	271
Total	1875	1165	619	394

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