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ON THE BEHAVIOUR OF THE FINNISH STOCK INDEX OPTIONS MARKETS*

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In this paper put-call-futures (PCF) parity and put-call-spot (PCS) parity are tested on the new Finnish stock index derivatives markets. Two levels of transaction costs are considered. Using daily closing price data, we find that, in particular, PCS parity is violated. The violations are due to the fact that the puts have been overpriced compared to the calls. The results suggest that the absence of an institutional framework for short selling of stocks is a factor contributing to discrepancies from price parities. Thus, option pricing in Finland is based on the futures price more than on the underlying index. (JEL G13)

1. Introduction

Following the success of stock index products in the U.S., the Finnish Options Market (FOM) began trading in May 1988. There was immediate acceptance of the new contracts and the volume of trading grew rapidly. Compared with the volumes on the Helsinki Stock Exchange (HeSE), the success of this new field has been remarkable. Altogether, the daily trading volume of the FOX (Finnish Options Index) derivatives may nowadays eclipse that of the stock market itself. At present, the products traded on the FOM include index options, index futures[1] contracts and stock futures.

Introduction of these new securities has resulted in many unexplored issues. In particular, the efficiency of the markets has been a subject of considerable research. One way to approach the test of market efficiency is to investigate the profitability of risk-free arbitrage opportunities. Actually, most option valuation models, including the famous Black-Scholes (B&S) model, are based on an arbitrage argument. In a continuous time framework, the arbitrage equilibrium is easily determined by a continuous hedging strategy. However, in an incomplete market with only finite opportunities to revise portfolios, no preference-free option price can be constructed with a portfolio of stocks and bonds (Levy 1985). Thus, Galai (1983) argues that testing market efficiency with the B&S model is more like testing the validity of the model

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[1] *In Finland, the contracts traded are actually closer to standardized forwards than futures (see Jokivuolle and Koskinen, 1990 or Puttonen, 1991). The difference between futures and forwards is that futures are settled daily (see e.g. Cox, Ingersoll and Ross, 1981).*

itself. In the discrete time case, Merton (1973a) had developed certain boundary conditions for options by using a simple dominance argument. Arbitrage strategies based on these conditions do not require continuous portfolio revising but rather the positions are assumed to be held until the expiration. As Galai (1983) has stated, the market cannot be shown to be inefficient (or nonsynchronous) for these weak conditions, and, at the same time, efficient for compatible but stronger assumptions. Therefore, in the case of a new market it makes sense to start the research with weaker conditions.

Like boundary conditions, put-call-spot parity and put-call-futures parity are free from investors' preferences. The original put-call(-spot)[2] parity was developed by Stoll (1969).[3] According to the model, a deterministic relationship should exist between European put and call prices if both options are written on the same underlying security and have the same striking price and expiration date. For American options, the simple equality of European put-call-spot parity does not hold, but only a pair of inequalities hold for them. This is because American options can be exercised prior to their expiration date and, e.g. Merton (1973a) has shown that an American put always has a positive probability of premature exercise. Merton (1973b), and Gould and Galai (1974) have later extended the put-call-spot parity to capture the effects of early exercise and dividend payments.

The advent of futures trading made it possible to make arbitrage also between options and futures contracts. As a result of the parity models, any two of the three instruments can be combined so that an instrument identical to the third one will be obtained. Furthermore, by combining these two models, we obtain a relationship between futures contracts and the underlying security. This pricing scheme is called the cost-of-carry model. These linkages among markets mean that inefficiencies in one market may be transmitted to all related markets.

Puttonen (1991) examined the Finnish stock index futures pricing for the period from May 1988 to December 1990. Using the cost-of-carry pricing model, the futures contract was found to have traded at a substantial discount especially at autumn time. The mispricing was assumed to be a result of the difficulties the arbitrageus faces when trying to sell the stocks short. In the Finnish market, there exists no institutional framework for short selling. In theory, however, the short sales restrictions cannot explain the substantial mispricing observed (Cornell and French, 1983). This is because the investors already holding the stocks have an opportunity to benefit from the mispricings (see Puttonen and Martikainen, 1991). Thus, the question of the effect of short sales restrictions in practice has not been fully solved.

This paper tests the parity models on the new FOX markets. The Finnish markets provide an interesting arena for empirical research of the put-call-spot parity since the options traded are European. Following Puttonen's (1991) results, it is interesting to see whether the underpricing of the futures contract has caused deviations either from put-call-spot parity or put-call-futures parity or both. In a frictionless market, violations from the cost-of-carry model would cause violations also from either PCS or PCF pricing model. Using B&S pricing model, Kahra and Kanto (1991) found that FOX put option implied standard deviations are usually larger than call option volatilities. This result suggests evidence to reject the PCS parity condition in the Finnish markets. The aim of this study is to examine whether the transaction costs have been large enough to prevent the arbitrage based on these models.

The remainder of this paper is organized as follows. In section 2, some basic properties for option and futures values in perfect capital markets are presented. Prices must satisfy these properties if there are to be no arbitrage opportunities. In section 3, transaction costs in the Finnish stock and derivatives markets are discussed. A description of the data follows in section 4. In section 5, the empirical results on tests of European put-call-futures parity and put-call-spot parity are illustrated. The tests are first carried out from the position of the most advantageously placed trader. If sustained deviations are found, the tests are repeated with transaction costs of a final customer who also incurs brokerage commis-

[2] *The term put-call-spot parity is used in this study to distinguish it from the put-call-futures parity.*

[3] *In fact, the put-call parity was first discussed in Castelli (1877).*

sions. After presenting the empirical results, discussion of the implications of the findings are presented. In the final section, conclusions from the behaviour of the Finnish stock index options markets are presented.

2. *The proposed tests*

To derive the put-call-futures parity, let us consider a portfolio A created by buying a futures contract and a portfolio B created by buying a call option and selling a put option with an equal striking price. Table 1 shows that regardless of the value of the underlying security, the difference between A and B portfolios are the same at the expiration. Hence, the present difference must, in equilibrium, be equal to $-(K-F)r^{-\tau}$. If the initial cash flow of the strategy were negative (the price of a put < the price of a call), the terminal inflow of portfolio B should exceed the inflow of portfolio A. The case would be opposite if the put were more expensive than the call. Because the outcome of the strategy is well known at current date, the value of one instrument is determined by the prices of other two instruments.

The put-call-futures parity can be written as

$$(1) \quad P-C=(K-F)r^{-\tau}$$

where
P = the put option price
C = the call option price
K = the striking price
F = the futures price
r = one plus the risk-free rate of interest over a given period and
τ = time to expiration i.e. the time between the maturity date T and current date t.

Table 2 illustrates the concept of put-call-spot parity. Instead of using the futures price as a basis for pricing calls and puts, the PCS parity portfolio contains the underlying stock index. From the table it is evident that the terminal difference between A and B strategies is K. The difference at current date must then be equal to $-Kr^{-\tau}$.

The put-call-spot parity can be written as

Table 1. Put-call-futures parity.

Strategy		Current date (t)	Value at expiration (T)	
			$S^*<K$	$S^*\geq K$
A	Buy a futures contract	0	S^*-F	S^*-F
B	Buy a call	$-C$	–	S^*-K
	Sell a put	$+P$	$-(K-S^*)$	–
		Total A – B	$K-F$	$K-F$

where S^* = price of the FOX basket (index) at expiration, K = the common striking price of call and put, C = price of a call, P = price of a put, F = price of a futures contract.

Table 2. Put-call-spot parity.

Strategy		Current date (t)	Value at expiration	
			$S^*<K$	$S^*\geq K$
A	Buy index	$-S$	S^*	S^*
B	Buy a call	$-C$	–	S^*-K
	Sell a put	$+P$	$-(K-S^*)$	–
		Total A – B	K	K

where S = price of the FOX basket (index) at current date, S^* = the index at expiration, K = the common striking price of call and put, C = price of a call, P = price of a put.

(2) $S = C - P + Kr^{-\tau}$

where
S = the level of the index

If the stock basket is paying cash dividends prior to the expiration date of options, the put option would be worth more and the call would be worth less than their payout-protected values. Let $D_{t,T}$ be the sum of the present values of all cash dividends to be paid between the current date t and the expiration date T.

The put-call-spot parity then becomes

(3) $S = C - P + Kr^{-\tau} + D_{t,T}$

The importance of put-call-futures parity and put-call-spot parity are similar to the Merton's (1973a) boundary conditions; any rational option valuation model must be consistent with these weaker conditions. If violations are found when testing the weaker conditions, they can be expected to reappear when testing more specific valuation models.

3. Transaction costs

Phillips and Smith (1980) provided an analysis of transaction costs for an arbitrageur operating in the U.S. stock and options markets. They argue that all the relevant factors, including both explicit and implicit costs, should be included in any study of market efficiency. The presence of transaction costs means that the price of an asset could fluctuate within a band around its theoretical value without representing a potential profit opportunity. The width of this band is determined by the transaction costs of the most favorably located arbitrageur.

There are several explicit costs in the Finnish markets that have to be considered.[4] First, if an arbitrageur acts as a broker on the HeSE, the only direct cost incurred is the stamp duty. The roundtrip stamp duty is 1.0 % consisting of 0.5 % when buying (selling) the stocks and 0.5 % when reversing the position. When building an arbitrage strategy, however, the exact value of index level at the maturity is not known. Thus, a conservative estimate must be used. In this study, the stamp duty was estimated to be 1.0 % of the current price of the index stocks. For a non-broker, the costs in the stock market also include a brokerage commission varying between 0.5 % and 1.0 %. In this study, the former estimate was used.

Although there exists no institutional framework for short selling of stocks in Finland, traders may borrow the stocks needed for arbitrage. This would, however, cause additional roundtrip stamp duty for that transaction. Furthermore, one probably has to pay some premium for the owner of the stocks. In addition to the direct costs, the current stock owners may face unpleasant tax consequences when selling the stocks. It is impossible to estimate the effect of these factors because they vary from one trader to another.

Traders on FOM can be divided into three categories: market makers, brokers and final customers. The explicit transaction costs for an arbitrageur acting as a market maker in the futures market consist of fixed commissions of FOM and a stamp duty. The commissions consist of a clearing fee when opening the position and a closing fee when reversing it. The total roundtrip commission was initially 48 marks but it was subsequently lowered to 26 marks in August, 1989. The stamp duty of 1 % is paid for the profit received from the reversed futures contract position. Thus, a rough estimate has to be made when constructing an arbitrage strategy. In this study, an estimate of 50 marks was made. This allows futures price increase or decrease of 10 % at the 500.000 index level. For a non-market maker, the one-way commission in the futures market was first 60 marks but it was lowered to 40 in May, 1990. The final customer also needs to count for a brokerage commission of about 60 marks.

In the FOX options market, estimating the explicit transaction costs is not as straightforward as in the stock and futures markets. If the arbitrageur acts as a market maker in FOM, the clearing fee when purchasing the option was 1.0 % of the premium in 1988. However, the fee was no less than 10 marks and no more than 26 marks. When reversing the position at the expiration, equal costs were incurred. When building an arbitrage strategy, the terminal value of the option was not known and the arbitrageur had to count for

[4] *Figures are based on conversations with staff members of the FOM and some brokerage houses.*

26 marks. In 1989, the clearing fee was lowered to 0.7 % (min 5 mk, max 16 mk). Furthermore, for premiums less than 10 marks no minimum level existed. This was mainly because there is a need in the market to realise the losses for the tax purposes. It made no sense to sell an option worth 1 mk and thus incur 5 mk transaction costs.

Since 1989 it has also been possible for market makers to pay a fixed amount of 15 000 mk (45 000 mk) per month and lower the commission to 5,5 mk (3,5 mk) per option. This complicates the question of calculating the arbitrage profits, because the arbitrage should be viewed from the position of the most advantageously placed trader. The question is similar to Phillips and Smith's (1980) argument that investment in the exchange seat establishes an opportunity cost. These costs are extremely difficult to allocate to a particular transaction. In this study, these fixed costs were ignored for simplicity. From the beginning of 1990, the trader had an opportunity to choose between three different commission systems. In this study, the arbitrageur was assumed to not pay any fixed amount in a month or to be under contract to trade some minimum amount of contracts in a month. The transaction costs were therefore estimated to be the same as in 1989. Also, the reversing commission was estimated to be 16 marks.

One-way transaction costs for a final customer in 1988 consisted of 1.7 % trading commission and 1.0 % (min 10 mk, max 26 mk) clearing fee. In 1989, the corresponding costs were 1.8 % plus 0.9 % (min 8 mk, max 26 mk) and in 1990 1.6 % plus 0.9 % (min 6,5 mk). Other costs incurred in the options market were the stamp duty and the brokerage commission varying between 2.0 % and 3.0 %. In this study, an estimate of 2.0 % will be used. The total roundtrip transaction costs for a final customer were thus as high as 10 – 13 %/premium. Although not directly comparable with Phillips and Smith (1980) results, these figures also indicate the great difference in the costs between a market maker and a final customer.

Implicit costs are more difficult to calculate. Implicit costs are usually estimated by the bid-ask spread, the difference between the highest quote to buy and the lowest offer to sell. Phillips and Smith (1980) and Bhattacharya (1983) were the first who argued that financial assets are generally bought at the ask price and sold at the bid price. As noted by Phillips and Smith, however, estimation of the appropriate magnitude of this cost is no simple matter and is not easily solved. In practice, trades occur also inside the spread, not only at the bid or ask. In this study, for options and futures contracts the actual bid ask spread was used. The bid and ask quotes of the stock market were not available for this study. Keim (1989) has provided statistics for bid-ask spreads for NYSE, AMEX and OTC NMC stocks on the U.S. markets. Stocks were grouped according to the market capitalization of the companies. The median spread for the four largest size deciles of the OTC NMC stocks was under 1 %. Thus, a rough estimate of 1 % market impact on the Finnish stock market was used in this study.

In the case of index derivatives arbitrage, there is always a choice between trading all the stocks in the index basket and using only some major stocks that closely match the index. In this study, we ignore the effect of tracking error. Furthermore, option and futures traders are subject to margin requirements. The margins can usually be posted in the form of stocks or Treasury bills on which investor continues to earn dividends and interest. Hence they are not a restriction for those who already own stocks or T-bills.

4. Description of the data

The FOX index is a capital-weighted index of 25 major stocks quoted on the HeSE. The trading value of the FOX stocks amounts to about 50 % of all stocks on the HeSE. The base figure of the index was set at 500 on May 7, 1988. The option contract size is set at 100 marks for each point of the index, so that when the index is at 600, 60 000 marks worth of stocks are controlled by a single option contract. Each futures contract is nominally equal to 100 times the futures price. FOX options and futures expire six times a year, i.e. in February, April, June, August, October and December. The last trading day is the fourth Thursday of the month. Both the option and futures contracts have cash settlement, which indeed is generally the case when the underlying asset is a portfolio.

The sample period is divided into three

parts; the first period is from August 29 to December 23, 1988, the second period is from 28 August to December 22, 1989 and the last period is from August 27 to December 21, 1990. The major motivation for choosing only periods from August to December was the findings of Puttonen (1991). He found that the futures contract has traded at discount especially during that period in years 1988–1990. The greatest violations occurred in September – December 1990, January – February 1990 and September – December 1989. The mispricings in the beginning of 1990 can partly be explained by the strike of bank employees at that time. The stock exchange then was highly illiquid making trading with stocks difficult. At that time, the actual market impact in the stock market was probably much more than 1 %.

Other factors that had an influence on selecting the sample periods were that no dividends were paid and the structure of the FOX basket remained the same during the periods. The dividend stream on the stocks in the FOX index is quite different from that of stocks in U.S. indices. Unlike their American counterparts, Finnish companies generally pay dividends only once a year, usually in May or April. Thus, dividend uncertainty is not a factor contributing to pricing inefficiency at autumn time.

All the data including the interest rates were kindly supplied by the market place. All the quotations are bid-ask prices at market close. The use of such data is problematic for study of mispricings. This is mainly because closing prices for different instruments may reflect trades made at different points in time. In the Finnish markets, the major difficulty concerns the relatively illiquid stock market. The stock index may respond to new information with a lag because not all the 25 stocks are traded continuously. In sharply moving markets the bias in favor of inefficient market will be greater. Thus, carefulness is needed when interpreting the results in times of heavy stock price fluctuations. Furthermore, in the options market especially deep-in-the-money and deep-out-of-money options may not be traded for long time periods. However, the bid and ask quotations are binding on the market makers who are committed to make at least one trade at these prices. In practice, maybe no more than one trade can be accomplished at these prices.

In total 4004 quotations of options and 500 quotations of futures contracts are used. Since autumn 1988, the volumes of option and futures trading had approximately doubled in a year. For example, in August 1989 the average option volume was about 130 000 contracts per month being about 60 000 during the corresponding period a year before. In 1990, trading in the futures market reduced remarkably but the options market remained quite actively traded. Being quite stable during autumn 1988, the index level decreased greatly in autumn 1989; in August 29 the index was at 648,69 and by November 23 it had dropped to 475,42. In autumn 1990, the index fluctuated between 314,90 and 347,17 index points.

As the risk-free interest rate daily quotations of the Helibor rate are used.[5] Helibor is commonly used as the analog of the short-term Treasury bill rate in the U.S. Since there is no interest rate for the maturity exactly matching the option and futures contracts each trading day, the rate nearest corresponding to the maturity is used. Although not exactly theoretically correct, the errors induced by this approximation are minimal. Similar to the index level, the level of Helibor rate was quite stable in autumn 1988, but fluctuated greatly in 1989 rising from 12,45 % in August 28, to 16,15 % in December 20. In autumn 1990, the interest rate reached its lowest point 12,17 % in September 10, and its peak 14,16 % in October 16.

5. *Empirical testing of price parities*

The empirical work in this chapter is based on equalities (1) and (2). After considering the explicit and implicit transaction costs, the put-call-futures parity can be expressed as

$$\text{(4a)} \quad \varepsilon_1 \equiv (C_a - P_b)r^{\tau} + K + TC_{(f,\,c,\,p)} - F_b \geq 0$$

$$\text{(4b)} \quad \varepsilon_2 \equiv F_a - (C_b - P_a)r^{\tau} - K + TC_{(f,\,c,\,p)} \geq 0$$

where

$C_{a/b}$ = ask/bid price of a call

[5] *Evidently, there exists a difference between lending and borrowing rates. It is suggested here, however, that for a large trader the difference is negligible.*

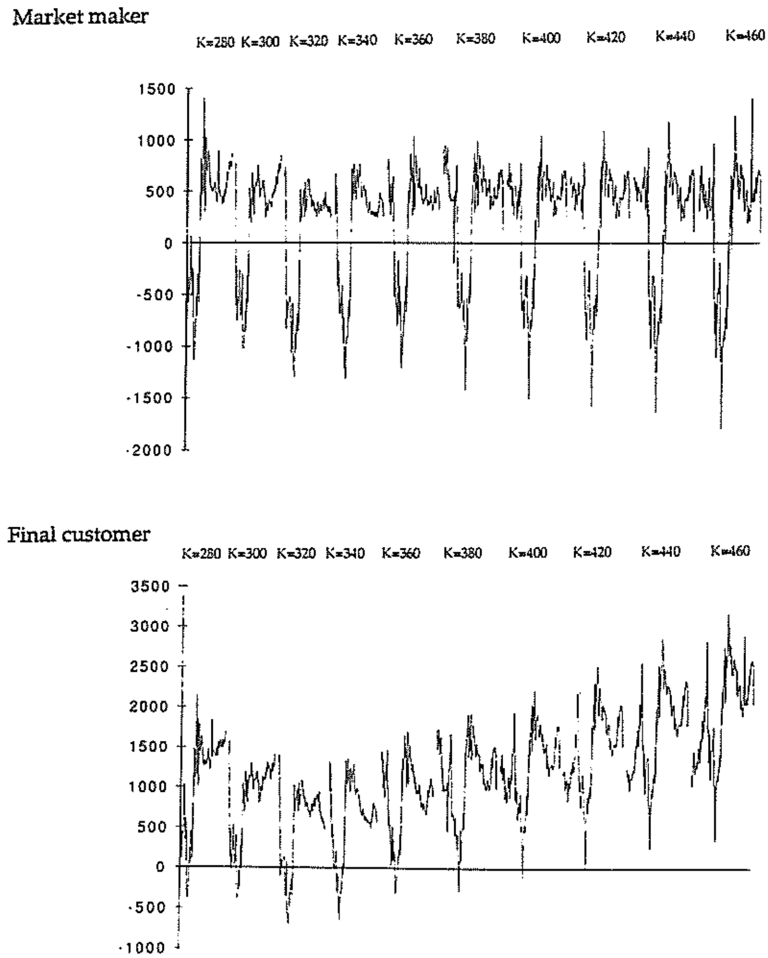

Figure 1. Put-call-futures arbitrage in autumn 1990. The horizontal axis is divided into ten time periods of 1–4 months by different striking prices. Figures below zero in the vertical axis represent arbitrage profits in Finnish marks.

$P_{a/b}$ = ask/bid price of a put
$F_{a/b}$ = ask/bid price of a futures contract
$TC_{(c,s,f)}$ = roundtrip transaction costs incurred in options (c), stock (s) and futures (f) markets

The inequality (4a) can be interpreted as testing the upper boundary of the futures contract and (4b) as testing the lower boundary. The tests were first carried out from the position of a market maker. In total, 920 hedges in 1988, 1580 hedges in 1989 and 1504 hedges in 1990 were constructed. Only one violation of the inequalities (4a) and (4b) was found when examining the parity bounds in 1988 and 1989. Correspondingly, only one violation from the inequality (4b) was found in 1990. However, the inequality (4b) was violated several times in 1990. Thus, the hypothesis of $\varepsilon_t \geq 0$ was rejected on grounds of Figure 1 and Table 3 results.

The horizontal axis is divided into ten time periods of 1–4 months. Figures below zero in the vertical axis represent arbitrage profit in Finnish marks. The results indicate strong violations from the upper boundary of the PCF parity. Figure 1 demonstrates that the violations occurred during the second quarter of the period. Of total 752 hedges, 192 were profitable. The mean mispricing magni-

Table 3. Violations from the PCF upper bound in autumn 1990.

K	N	f	(*)	f%	(*)	|min|	|max|	|mean|	(*)	std.dev.
280	62	17	(3)	27.4	(4.8)	5.1	1138.8	518.6	(324.6)	309.5
300	64	18	(7)	28.1	(10.9)	232.4	1024.6	620.5	(203.1)	247.9
320	66	19	(12)	28.8	(18.1)	184.2	1316.5	795.3	(348.1)	290.8
340	67	19	(10)	28.4	(14.9)	163.0	1326.7	697.5	(268.5)	307.1
360	73	19	(4)	26.0	(5.4)	50.3	1208.1	611.2	(193.9)	298.0
380	84	20	(1)	23.8	(1.2)	97.0	1470.9	598.7	(331.6)	300.6
400	84	19	(1)	22.6	(1.2)	235.4	1512.1	645.4	(150.7)	300.8
420	84	20		23.8		56.0	1617.5	678.7		339.7
440	84	20		23.8		104.8	1648.5	718.6		360.4
460	84	21		25.0		63.2	1802.2	737.7		407.7
Σ	752	192	(38)	25.5	(5.0)					

where K = striking price of options, N = number of observations, f = violation frequency, f% = percentage frequency, |min| = absolute value of the minimum violation (in marks), |max| = absolute value of the maximum violation, |mean| = average magnitude of violations, Σ = total, (*) figures in parentheses denote the profits from the position of a final customer.

tude was over 500 marks per contract. For a final customer, the frequency of arbitrage opportunities decreased to 38 cases. These findings are similar to those of Rindell (1989) on the Swedish markets with the exception that violations from the upper boundary have been much greater in the Finnish markets.

The frequency and magnitude of the violations are surprising, but carefulness is needed when interpreting the results because, as mentioned before, the futures trading volume was quite low in 1990. Thus, perhaps no more than one arbitrage trade can be accomplished at each price. However, the results suggest that several arbitrage opportunities for a market maker have been available. The violations at the final customer's transaction cost level occurred for in-the-money calls and out-of-the-money puts which are not actively traded contracts. However, the accuracy of the data should not cause problems since the quotations of both options and futures are prices at market close and the bid-ask spread is taken into account when implementing the arbitrage strategy. Moreover, violations were found across all the striking prices when considering the transaction costs of a market maker, Thus, the results suggest that arbitrage opportunities have been available.

From the results above we conclude that put-call-futures parity was violated in autumn 1990. On grounds of these results and findings in Puttonen (1991) that the futures contract has traded under its theoretical value, the mispricings are supposed to be of even greater magnitude when testing the put-call-spot parity.

Stoll (1969) employed a regression technique when testing the put-call-spot parity for the first time. It has been later suggested (Gould and Galai, 1974), however, that such a technique is based on averaging, while for market inefficiency only outliers are of interest. Similar to the put-call-futures parity, inequalities from the put-call-spot parity can be expressed as

$$\text{(5a)}\quad \varepsilon_3 \equiv C_a - P_b + Kr^{-\tau} + TC_{(s,c,p)} + D_{t,T} - S \geq 0$$

$$\text{(5b)}\quad \varepsilon_4 \equiv S - C_b + P_a - Kr^{-\tau} + TC_{(s,c,p)} - D_{t,T} \geq 0$$

An equal number of short and long hedges[6] were constructed. In the U.S. markets, one would expect to find proportionately more violations of (5a) than of (5b). This was explained by the risk in realising the profit of a short hedge (Klemkosky and Resnick, 1979). Short sales may only be executed on an upstick and delays in executing the orders are possible. Thus, before an order is executed the stock prices can change. In the Finnish markets, the absence of institutional framework

[6] *Short hedge is based on inequality (5a) and long hedge on (5b).*

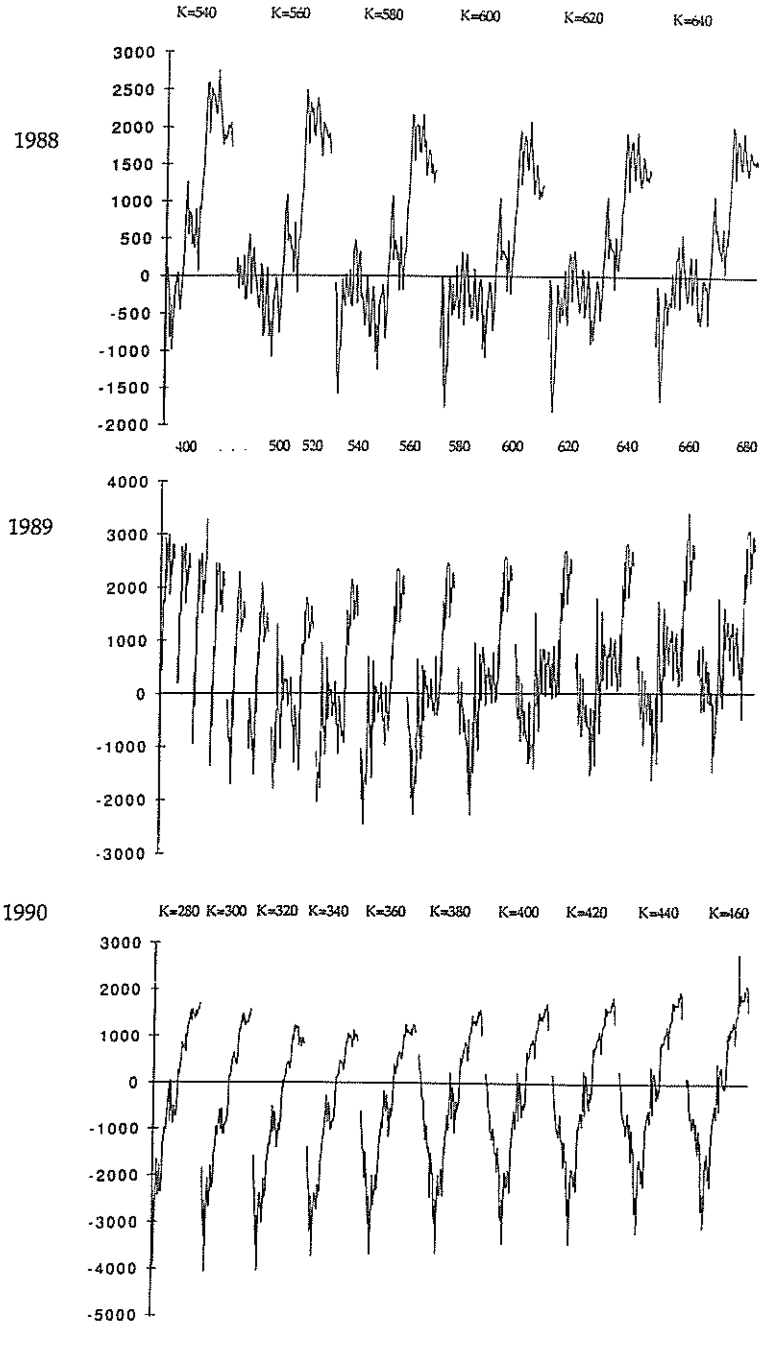

Figure 2. Put-call-spot parity from the position of a final trader.

for short selling is assumed to have caused even greater violations from the inequality (5a). Figure 2 and Table 4 demonstrate the results regarding the profitability of a short hedge.

The results in the figure are from final cus-

Table 4. Summary of profitable PCS parity short hedges.

1988

K	N	f	(*)	f%	(*)	|min|	|max|	|mean|	(*)	std.dev.
540	53	28	(11)	52.8	(20.8)	72.4	1847.1	846.3	(417.8)	478.7
560	76	51	(26)	67.1	(34.2)	49.9	1907.1	948.5	(373.1)	399.1
580	82	56	(37)	68.3	(45.1)	340.5	2695.5	1145.5	(498.9)	513.2
600	83	59	(39)	71.0	(47.0)	7.4	2831.7	1140.7	(486.9)	567.3
620	83	58	(37)	69.9	(44.6)	6.9	2878.9	1163.8	(476.6)	571.2
640	83	59	(32)	71.0	(38.6)	25.7	2771.6	1127.8	(445.2)	565.3
Σ	460	311	(182)	67.6	(39.6)					

1989

K	N	f	(*)	f%	(*)	|min|	|max|	|mean|	(*)	std.dev.
400	19	3	(–)	15.8	(–)	340.1	745.1	549.3	(–)	202.8
420	19	3	(–)	15.8	(–)	361.9	840.9	645.0	(–)	251.1
440	20	5	(3)	25.0	(0.15)	262.4	1833.4	971.3	(466.7)	606.7
460	21	8	(4)	38.1	(19.0)	0.9	2178.8	953.5	(852.6)	834.3
480	26	12	(9)	46.2	(34.6)	114.2	2487.2	1299.2	(804.7)	704.6
500	29	15	(12)	51.7	(41.4)	178.0	2363.1	1274.3	(724.2)	648.5
520	60	43	(30)	71.7	(50.0)	67.9	2820.1	1340.1	(724.8)	655.2
540	60	44	(33)	73.3	(55.0)	5.8	3115.7	1385.0	(752.2)	715.6
560	62	46	(31)	74.2	(50.0)	127.1	3472.8	1415.8	(850.8)	786.6
580	67	51	(34)	76.1	(50.7)	157.7	3247.0	1360.1	(755.4)	743.1
600	77	60	(34)	77.9	(44.2)	84.3	3307.6	1225.4	(689.4)	709.9
620	81	65	(30)	80.2	(37.0)	0.9	2507.9	1093.1	(628.8)	633.0
640	83	67	(24)	80.7	(28.9)	819.7	2788.7	1022.8	(651.3)	680.5
660	83	65	(24)	78.3	(28.9)	16.6	2998.4	1036.1	(497.5)	647.6
680	83	65	(19)	78.3	(29.2)	55.4	3006.7	1004.7	(399.1)	663.1
Σ	790	552	(287)	69.9	(36.3)					

1990

K	N	f	(*)	f%	(*)	|min|	|max|	|mean|	(*)	std.dev.
280	62	39	(32)	62.9	(51.6)	22.6	4507.4	1684.4	(1389.1)	1104.4
300	64	44	(35)	68.8	(54.7)	27.6	4665.0	1750.4	(1621.4)	1175.9
320	66	47	(39)	71.2	(59.1)	30.1	4635.1	1871.8	(1713.7)	1229.1
340	67	45	(38)	67.2	(56.7)	110.1	4377.2	1892.4	(1658.7)	1157.7
360	73	49	(44)	67.1	(60.3)	110.4	4441.4	1916.7	(1487.9)	1060.0
380	84	60	(50)	71.4	(59.5)	84.5	4530.8	1752.7	(1344.9)	1073.8
400	84	60	(49)	71.4	(58.3)	78.0	4443.5	1801.4	(1324.4)	1038.8
420	84	61	(50)	72.6	(59.5)	2.2	4557.7	1784.4	(1229.8)	1076.7
440	84	61	(51)	72.6	(60.7)	32.0	4451.0	1787.2	(1090.2)	1079.7
460	84	61	(42)	72.6	(50.0)	1.3	4484.0	1825.6	(1212.2)	1101.7
Σ	752	527	(430)	70.1	(57.2)					

where K = striking price of options, N = number of observations, f = violation frequency, f% = percentage frequency, |min| = absolute value of the minimum violation (in Finnish marks), |max| = absolute value of the maximum violation, |mean| = average magnitude of violations, Σ = total, (*) figures in parentheses denote the profits from the position of a final customer.

tomer's point of view. Several violations were found. There seems to be a clear relationship between time to maturity and the proportion of deviations from the parity condition. This result is inconsistent with Klemkosky and Resnick's (1979) findings. This may be due to the fact that option pricing in the Finnish stock index market seems to be based on the futures price rather than the underlying index. When the futures price deviates from its theoretical value, the option prices will also violate the theoretical pricing bounds. Close to the expiration the futures price and the index must, by definition, approach each other. Thus, the PCS parity and PCF parity become almost equal. Contrary to these findings, only one minor violation in 1990 was found when testing the inequality (5b). The finding that a short hedge is more profitable than a long one is similar to the results of Klemkosky and Resnick (1979) and Rindell (1989). Furthermore, the deviations from the inequality (5a) are of greater magnitude than observed in prior studies.

These results are consistent with the findings of Kahra and Kanto (1991). The put options seem to have been overpriced with respect to the call options on the Finnish markets. For the case of market maker, there were 1390 mispricing signals out of total 2002. This finding is consistent with Klemkosky and Resnick (1979) results. It must be noted, however, that they examined stock options, not index derivatives. So, the magnitude of profits cannot be directly compared. The violations on the Finnish markets were of great magnitude even after considering the transaction costs of a final customer. The greatest mispricings occurred in 1990 when 57,2 % of all hedges were profitable. The average profit for a final customer was over 1000 marks per contract.

6. *Discussion*

Before final statements, some shortcomings of this paper are discussed. All the tests in this study were carried out as ex-post tests. Galai (1978) has argued that tests like this can only indicate whether the markets are nonsynchronized or not continuously in equilibrium. To test market efficiency, an *ex ante* test should be carried out. The relevant question for studying market efficiency is, whether traders can make arbitrage profits by trading at t + 1 given the information at point t. *Ex post* tests are based on an assumption that the position can be immediately executed at time t.

In this study, the actual bid and ask prices were employed. By working only with the widest band of available bid-ask spread the tests have possibly been biased in favor of the null hypothesis (Phillips and Smith 1980, Bhattacharya 1983). The data available did not allow us to use any other estimate. Thus, it is probable that only one trade at given bid or ask price is possible to be completed. An interesting topic for further research would be to examine the depth of the markets and its effect on trading prices. For this purpose, however, better data will be needed.

7. *Conclusions and further research*

This study examines the relations between prices of the Finnish Options Index (FOX) derivative securities and the underlying portfolio of stocks traded on the Helsinki Stock Exchange (HeSE). Two level of transaction costs were employed. The empirical results of the put-call-futures parity were approximately consistent with the model when the transaction costs of a final trader were considered. Market makers, however, had several arbitrage opportunities in autumn 1990.

When testing the put-call-spot parity, several violations were reported even when the transaction costs of a final trader were considered. The profitability of short hedges can mostly be explained by the difficulties in short selling of stocks on the Finnish markets. The results suggest that current stock owners have not yet begun trading in the new derivative markets on a large scale. This finding is consistent with findings of Puttonen (1991). It must be remembered, however, that there are certain problems related also to the stock owners arbitrage. Firstly, there may be tax consequences of selling stocks and secondly, the arbitrageur may find it impossible to sell the exact FOX basket. In practice, it is impossible to estimate the effect of these factors exactly.

Restrictions on trading and the execution risk in the stock market are more important in the Finnish derivative markets than in the corresponding U.S. markets. Thus, violations from basic rational conditions can be found. It should be pointed out, however, that *ex ante* tests should be carried out before making conclusions concerning the market efficiency. An obvious topic for further research would be to test these conditions in an *ex ante* manner by constructing the hedges using actual prices just after the mispricing identification. Another interesting topic for further research might be to empirically investigate the PCS and PCF parity implied interest rates following Brenner and Galai (1986), and Frankfurter and Leung (1991).

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