Put-Call Parity with Futures-Style Margining

by

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May 1996

WORKING PAPER NO. 57

Not for quotation. Comments welcome.

1 The author would like to thank Rob Brown, Stephen Chambers, Peter Easton, Jack English, Robert Faff, Barry Goss, Paul Kofman, Paul Lalor, Martin Martens, Patricia McBride, Keith McLaren, Sean Pinder, two anonymous referees and seminar participants at Macquarie University and Monash University for helpful comments. The study was funded by a grant from the Australian Research Council.

ABSTRACT

Lieu (1990) derived the put-call parity relationship for futures and futures option contracts where futures-style margining occurs on the option contracts. The Sydney Futures Exchange uses futures-style margining for options and hence provides a suitable market to test this relationship. Further, since January 1993 time-precise transactions data have been maintained by the exchange.

This paper uses all contracts for which futures options are traded on the Sydney Futures Exchange. The study period is from January 1993 to December 1994. After allowing for the effects of non-simultaneity, it is found that in-the-money put and call options are underpriced by a small amount when compared with the parity relationship.

PUT-CALL PARITY WITH FUTURES-STYLE MARGINING

1. Introduction

The put-call parity relationship for futures options has been investigated by Ball and Torous (1986), Jordan and Seale (1986) and Followill and Helms (1990). Ball and Torous examined the parity relationship for American futures option, that is:

$$F_t e^{-r(\tau - t)} - X \leq C_t - P_t \leq F_t - X e^{-r(\tau - t)} \tag{1}$$

where F_t = futures price at time t;

X = exercise price;

C_t = call option price at time t;

P_t = put option price at time t;

r = risk-free rate of interest;

t = the time of the trade; and

τ = the expiry date for all contracts.

They used closing and settlement prices for options on three futures contracts traded on three United States futures exchanges for the period from October 1982 to March 1985. Close conformity was found between the closing and settlement prices and the parity relationship. However, as noted by Followill and Helms, such a result is not surprising as exchange settlement committees often specify settlement prices according to the models that are being tested.

Jordan and Seale and Followill and Helms examined the parity relationship for European futures options, that is:

$$(F_t - X)e^{-r(\tau - t)} - C_t + P_t = 0 \qquad (2)$$

Jordan and Seale used transactions data to examine US treasury bond futures options, and found that departures from the parity relationship were small, with profits generally being confined to floor traders. Followill and Helms used transactions data to examine US gold futures options, and they too found evidence of some small departures from the parity relationship.

All of these studies related to markets where there was no futures-style margining of the option contracts. But Lieu (1990) has derived the put-call parity relationship for futures and futures option contracts where futures-style margining occurs on the option contracts. Specifically he showed that under this condition the put-call parity relationship is:

$$F_t - X - C_t + P_t = 0 \qquad (3)$$

In his paper, Lieu (1990, p.334) stated that it is not possible to test this theorem because there is no suitable markets that use futures-style margining for options. However, Chen and Scott (1993) showed that the put-call parity relationship that Lieu derived also applies to options on interest rate futures contracts. Therefore, the relationship could be examined using interest rate futures contracts traded on the London International Financial Futures Exchange.

The relationship derived by Lieu can also be tested by examining contracts traded on the Sydney Futures Exchange since all contracts traded on that exchange, including futures options, are subject to marking-to-market at the end of each day's trading. Further, since January 1993 time-precise transactions data have been maintained by the Exchange. These data are sourced directly from the verbal record of each trade as it occurs in the trading pits.

Information provided by the Sydney Futures Exchange states that this data is time-precise to the nearest second.[1]

The purpose of this paper is to use all contracts traded on the Sydney Futures Exchange to examine the parity relationship in a market where futures-style margining is used. This is achieved by using all trades in all futures contracts, together with all trades in the related futures options contracts, from January 1993 to December 1994.[2]

A knowledge of the derivation of the put-call parity relationship is required to enable empirical tests of the relationship to be constructed. As a result the relationship is derived in Section 2. The data are described in Section 3, while the results are discussed in Section 4. A summary is provided in Section 5.

2. Put-Call Parity with Futures-Style Margining

Following Lieu (1990), Equation 3 may be proven as follows.[3] Suppose that this equation did not hold and it was observed in the market at time t that $F_t - X - C_t + P_t > 0$. In these circumstances an arbitrage opportunity is present. If we make the usual frictionless markets assumptions, including the assumption that it is possible to borrow and lend at the risk-free rate of interest, then the transactions needed to exploit this opportunity may be shown as follows.

A portfolio is established on day one by taking a long position in $e^{-r(\tau - t)}$ units of the call option (at price C_t) and short positions in $e^{-r(\tau - t)}$ units of the futures contract (at price F_t) and $e^{-r(\tau - t)}$ units of the put option (at price P_t). On the second day, a portfolio is established by taking a long position in $e^{-r(\tau -(t-1))}$ units of the call option (at price C_{t+1}) and short positions in units $e^{-r(\tau -(t-1))}$ of the futures contract (at price F_{t+1}) and $e^{-r(\tau -(t-1))}$ units of the put option (at price P_{t+1}). On the third day, a portfolio is established by taking a long position in $e^{-r(\tau - (t-2))}$ units of the call option (at price C_{t+2}) and short positions in $e^{-r(\tau - (t-2))}$ units of the futures contract (at price F_{t+2}) and $e^{-r(\tau - (t-2))}$ units of the put option (at price P_{t+2}). This procedure is repeated each day until the expiry of the futures contract.

At the end of the first day, the contracts are marked-to market and the long position in the call option registers a gain (loss) of $e^{-r(\tau - t)}[C_{t+1} - C_t]$. On the second day, the gain (loss) on the long position in the call option is $e^{-r(\tau - (t-1))}[C_{t+2} - C_{t+1}]$, and on the third day, the gain (loss) is $e^{-r(\tau - (t-2))}[C_{t+3} - C_{t+2}]$. If each of these daily gains (losses) is invested (borrowed) at the risk-free rate of interest until the expiry of the futures contract, the terminal value of the long positions taken in the call option is:

$$
\begin{aligned}
& e^{-r(\tau - t)}[C_{t+1} - C_t]\, e^{r(\tau - t)} + \\
& e^{-r(\tau - (t-1))}[C_{t+2} - C_{t+1}]\, e^{r(\tau - (t-1))} + \\
& e^{-r(\tau - (t-2))}[C_{t+3} - C_{t+2}]\, e^{r(\tau - (t-2))} + \\
& \ldots + e^{-r}[C_\tau - C_{\tau-1}]\, e^{r} \\
& = C_\tau - C_t
\end{aligned}
$$

Given that $C_\tau = 0$ if $F_\tau < X$, and $C_\tau = F_\tau - X$ if $F_\tau \geq X$, the terminal value of the long positions taken in the call option is $-C_t$ if $F_\tau < X$, and $F_\tau - X - C_t$ if $F_\tau \geq X$.

It may also be shown that the terminal value of the short positions in the futures contract is $F_\tau - F_t$, and the terminal value of the short positions in the put options is $X - F_\tau - P_t$ if $F_\tau < X$ and $-P_t$ if $F_\tau \geq X$. The terminal value of the portfolio is therefore:

$$- C_t - [F_\tau - F_t] - [X - F_\tau - P_t] = - C_t + F_t - X + P_t \text{ if } F_\tau < X,$$

and $[F_\tau - X - C_t] - [F_\tau - F_t] - [-P_t] = - X - C_t + F_t + P_t$ if $F_\tau \geq X$.

Therefore, for all F_τ, the terminal value of the portfolio is:

$F_t - X - C_t + P_t$

Given that $F_t - X - C_t + P_t$ is positive, an arbitrage profit has been made.

Conversely, if it is observed in the market at time *t* that $F_t - X - C_t + P_t < 0$, then the same analysis is applied by taking short positions in the call option, and long positions in the futures contract and the put option. The terminal value of the portfolio is $-F_t + X + C_t - P_t$. Given that this value is positive, an arbitrage profit has been made. Therefore, an arbitrage opportunity is present unless $F_t - X - C_t + P_t = 0$. It should be noted that the assumption of being able to borrow and lend at the risk-free rate of interest results in all interim net cash flows being zero.

3. Data

To examine the put-call parity relationship, data in the four major contracts that are traded on the Sydney Futures Exchange are examined. These are the All-Ordinaries Share Price Index Contract, the 90-Day Bank Accepted Bill Contract, and the 3-Year and 10-Year Treasury Bond Contracts. These data comprise all contracts for which futures options are traded.

The All-Ordinaries Share Price Index contract is based on the value of the Australian Stock Exchange All-Ordinaries Index multiplied by \$25, and is quoted to one full index point. The 90-Day Bank Accepted Bill contract is based on a 90-day bank accepted bill with a face value of \$100 000, and trades are quoted at one hundred minus the annual percentage yield to two decimal places. The 3-Year (10-Year) Treasury Bond contract is based on a 3-Year (10-Year) government bond with a face value of \$100 000, offering a coupon rate of 12 per cent per annum payable half yearly. Trades are quoted at one hundred minus the annual percentage yield, with a minimum fluctuation of 0.005.

Since January 1993 the Sydney Futures Exchange has maintained a trade-by-trade record of the time, price and volume of every contract traded. These data are sourced directly from the verbal records of each trade as it occurs in the trading pits. The time of the trade is recorded accurately to the nearest second.

Table I shows the *number* of trades from January 1993 to December 1994 for each of four contracts.

INSERT TABLE I HERE

From Table I it may be seen that of the total number of trades in these contracts, more than 95 percent were in the futures contracts. The total number of trades in the call options was similar to the number of trades in the put options. Less than one-quarter of the number of trades in call and put options were in-the-money.

Table II is similar to Table I but shows the total *volume* of trades on each of the four contracts. For the All-Ordinaries Share Price Index Contract, 67 percent of the volume of trades was in the futures contract. For the 90-Day Bank Accepted Bill Contract, this figure was 89 percent, while for the 3-Year (10-Year) Treasury Bond Contract, this figure was 92 (84) percent. The difference between Table I and Table II is due to the greater average volume of contracts per trade for futures options than for the futures contracts. Again, less than one-quarter of the volume of trades in call and put options were in-the-money.[4]

INSERT TABLE II HERE

Futures options traded on the Sydney Futures Exchange are American, that is, they can be exercised prior to the expiry date. However, Lieu (1990) and Chen and Scott (1993) showed that American futures options with futures-style margining should not be exercised prior to the expiry date. Given that all gains (losses) are registered daily via the marking-to-market of all positions, exercise prior to the expiry date is not rational. Consistent with their analyses, options on the Sydney Futures Exchange are very rarely exercised prior to the expiry date. For example, during 1994, only 6 options on the All-Ordinaries Share Price Index Contract were exercised prior to the expiry date, 40 options on the 90-Day Bank Accepted Bill Contract were exercised prior to the expiry date, while 40 (300) options on the 3-Year (10-Year) Treasury Bond Contract were exercised prior to the expiry date.[5]

The data screening procedure that was used exploits the fact that approximately 95 percent of the total number of trades occur in the futures contract. Given the heavy trading in that contract, a *set* of futures prices may be used to examine the effects of non-simultaneity between option prices and the prices of the underlying futures contract. If a particular pricing relationship is found using *each of the set* of futures prices matched to put and call options with respect to exercise price and expiration month, then it may be inferred that that relationship is robust to the effects of non-simultaneity.

The following procedure was used to match put and call options with the same exercise price and expiration month, with a *set* of transactions in the underlying futures contract. Firstly, all prices for matching contracts (that is, contracts with the same exercise price and expiration month), were collected where:

$$F_1, P_2, F_3 \ldots\ldots F_{n-2}, C_{n-1}, F_n,$$
$$\text{or} \quad F_1, C_2, F_3 \ldots\ldots F_{n-2}, P_{n-1}, F_n, \qquad (4)$$

where F_1 is the last trade in the futures contract that precedes the trades in the put and call options, P is the trade in the put option, C is the trade in the call option, $F_3 \ldots F_{n-2}$ are all the trades in the futures contract that occur between the trades in the options, F_n is the first trade in the futures contract that follows the trades in the options, and where the time period between the trading of F_1 and F_n is less than *T*. *T* takes on three values, namely 90, 120, and 150 seconds.[6] It should be noted that to be included in the sample, it is not necessary for there to be any trades in the futures contract *between* the trades in the options (that is, $F_3 \ldots F_{n-2}$ need not exist).

For each set of contracts, F_H is defined as the maximum futures price from F_1 to F_n, including $F_3 \ldots F_{n-2}$. Similarly, F_L is defined as the minimum futures price from F_1 to F_n, including $F_3 \ldots F_{n-2}$.

Given the heavy trading in the futures contract, this procedure is designed to allow for changes in conditions affecting equilibrium that may occur within the time period *T*. If, for example, a trading strategy involves taking a short position in the futures contract, and if that strategy is profitable using F_L, then we may infer that Equation 3 is not an accurate representation of the pricing relationship. Similarly, if a trading strategy involves taking a long position in the futures contract, and if that strategy is profitable using F_H, then we may again infer that Equation 3 is not an accurate representation of the pricing relationship.

As a second step in the screening procedure, where there was more than one trade in either the put or the call option, only those matching contracts that minimised the time period between the trading of the put and the call option were selected.

4. Results

Table III presents an analysis of the extent to which Equation 3 provides an accurate representation of the pricing relationship. For this analysis, F_1 from Equation 4 is used as the futures price. (The analysis was repeated using F_n. The results were virtually identical, and therefore are not reported.) For each contract, when all observations are considered, there is no evidence of any systematic violation of Equation 3. For example, when the time period between F_1 and F_n is less than 90 seconds, there are 93 observations for the All-Ordinaries Share Price Index contracts. Of these observations, 35 provide positive values for $F_1 - X - C + P$, while 44 provide negative values. From Table III it may be seen that for each contract and for each value of *T*, the median value of $F_1 - X - C + P$ is zero. The precise parity relationship is observed in over 15 percent of cases for the All-Ordinaries Share Price Index contract, and between one-quarter and one-third of cases for the other three contracts.

But systematic violations of the parity relationship are found when the observations are categorised as to whether the futures price is greater than, or less than or equal to, the exercise price. To test this relationship, a 2 x 2 chi-square statistic was calculated by comparing the expected and actual numbers of observations in four categories.[7] These categories were: first where $F_1 > X$ and $F_1 - X - C + P > 0$; second where $F_1 > X$ and $F_1 - X - C + P < 0$; third where $F_1 \leq X$ and $F_1 - X - C + P > 0$; and fourth where $F_1 \leq X$ and $F_1 - X - C + P < 0$. If put-call parity as shown in Equation 3 is an accurate representation of the pricing relationship, then no relationship between these variables should be found. Deviations of $F_1 - X - C + P$ from zero should be random. However, in all except one case the chi-square statistic was significantly different from zero at the 0.01 level.[8]

The analysis in Table III suggests that when $F_1 > X$, then on average $F_1 - X - C + P > 0$. Where $F_1 > X$, call options are in-the-money, and put options are out-of-the-money. Since in such cases on average F_1 - X - C + P > 0, this suggests that in-the-money call options tend to be underpriced when compared with the parity relationship, while out-of-the-money put options tend to be overpriced when compared with the parity relationship. Table III also suggests that when $F_1 \leq X$, then on average $F_1 - X - C + P < 0$. Where $F_1 < X$, call options are out-of-the-money, and put options are in-the-money. Since in such cases on average $F_1 - X - C + P < 0$, this suggests that out-of-the-money call options tend to be overpriced when compared with the parity relationship, while in-the-money put options tend to be underpriced when compared with the parity relationship. In summary therefore, in-the-money call and put options tend to be underpriced when compared with the parity relationship, while out-of-the-money call and put options tend to be overpriced when compared with the parity relationship.

INSERT TABLE III HERE

The analysis in Table III suggests that when $F_1 > X$, then on average $F_1 - X - C + P > 0$, and when $F_1 \leq X$, then on average $F_1 - X - C + P < 0$. The arbitrage strategy to exploit such a relationship is as follows. Where $F_1 > X$, a long position is taken in the call option, and short positions are taken in the futures contract and the put option. To allow for the effect of non-simultaneity between the trades in the put option, the call option, and the futures contract, the short position in the futures contract is taken at the least favorable futures price, namely F_L. Where $F_1 \leq X$, a short position is taken in the call option, and long positions are taken in the futures contract and the put option. In these cases, to allow for the effect of non-simultaneity, the long position in the futures contract is taken at F_H. To the extent that non-simultaneity might have an impact on the results, this procedure will result in a bias *against* finding a positive relationship between $F_1 - X$ and $F - X - C + P$. To further minimize the effects of non-simultaneity, all observations were deleted where $F_H - F_L$ exceeded one tick size. The results from this analysis are provided in Table IV.

INSERT TABLE IV HERE

After allowing for the effect of non-simultaneity, the extent of the apparent violations from the parity relationship are significantly reduced. But for the All-Ordinaries Share Price Index contract, and the 3-Year Treasury Bond contract, there remains some evidence of a positive relationship between $F_1 - X$ and $F - X - C + P$. This is especially true for the 3-Year Treasury Bond contract. The precise parity relationship is observed in over 13 percent of cases for the All-Ordinaries Share Price Index contract, and between one-quarter and one-third of cases for the other three contracts.

To examine the parity relationship further the samples for each contract were broken into quintiles based on the rank of $F_1 - X$.[9] The results from this analysis are provided in Table V.

INSERT TABLE V HERE

The results provided in Table V also show a strong relationship between $F_1 - X$ and $F_1 - X - C + P$. For all four contracts, a 5 x 2 chi-square statistic was calculated by comparing observations in the quintiles formed on $F_1 - X$ with observations where $F_1 - X - C + P > 0$ and $F_1 - X - C + P < 0$. In all cases, this statistic was significantly different from zero at the 0.05 level. While this apparent violation of the parity relationship is persistent, its magnitude is small. Within all of the quintiles across the four contracts, the median violation only ranges from zero to \$142. Brochures provided by the Sydney Futures Exchange suggest that the transaction costs associated with attempting to undertake arbitrage trading would exceed \$150.

5. Summary

In this paper all contracts for which futures options are traded on the Sydney Futures Exchange were used to examine the put-call parity relationship where futures-style margining occurs for the option contracts. All trades that occurred between January 1993 and December 1994 were studied. The precise parity relationship was observed in between 15 percent and one-third of all cases, depending on the contract. The only systematic violation that was detected was that in-the-money put and call options were found to be underpriced by a small amount when compared with the parity relationship.

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Table I
Number of Trades by Contract on the Sydney Futures Exchange from January 1993 to December 1994

	All-Ordinaries Share Price Index	90-Day Bank Accepted Bills	3-Year Treasury Bonds	10-Year Treasury Bonds
Futures Contract	375 134	292 209	342 482	513 650
Call Option Contract	8 536	7 473	6 508	13 483
Call Option Contract (F>X)[a]	2 117	1 698	1 389	2 442
Call Option Contract ($F \leq X$)	6 419	5 775	5 119	11 041
Put Option Contract	6 855	8 812	5 809	12 270
Put Option Contract (F>X)	5 752	6 477	4 796	10 620
Put Option Contract ($F \leq X$)	1 103	2 335	1 013	1 650

[a] The futures price used to categorise options as either in- or out-of-the-money was obtained from the futures contract (with the same expiration month) that traded immediately prior to the option trade.

Table II
Volume of Trades by Contract on the Sydney Futures Exchange from January 1993 to December 1994

	All-Ordinaries Share Price Index	90-Day Bank Accepted Bills	3-Year Treasury Bonds	10-Year Treasury Bonds
Futures Contract	2 537 130	12 404 161	10 933 246	7 702 736
Call Option Contract	653 078	758 263	521 122	779 158
Call Option Contract (F>X)[a]	148 321	135 275	112 871	123 299
Call Option Contract (F≤X)	504 757	622 988	408 251	655 859
Put Option Contract	571 469	843 418	480 358	706 795
Put Option Contract F>X)	514 075	652 356	408 744	619 049
Put Option Contract (F≤X)	57 394	191 062	71 614	87 746

[a] The futures price used to categorise options as either in- or out-of-the-money was obtained from the futures contract (with the same expiration month) that traded immediately prior to the option trade.

Table III
Test of Put-Call Parity Relationship with Futures-Style Margining

T (in seconds)		All-Ordinaries Share Price Index			90-Day Bank Accepted Bill			3-Year Treasury Bond			10-Year Treasury Bond		
		$F_1>X$	$F_1 \le X$	All	$F_1>X$	$F_1 \le X$	All	$F_1>X$	$F_1 \le X$	All	$F_1>X$	$F_1 \le X$	All
90	F_1-X-C+P>0[a]	19[b]	16	35	25	15	40	49	21	70	100	68	168
	F_1-X-C+P=0	8	6	14	17	22	39	31	40	71	64	63	127
	F_1-X-C+P<0	11	33	44	9	24	33	30	63	93	87	106	193
	Total	38	55	93	51	61	112	110	124	234	251	237	488
	χ^2[c]		7.10**			9.02**			22.78**			7.51**	
120	F_1-X-C+P>0	27	20	47	34	21	55	64	33	97	120	77	197
	F_1-X-C+P=0	12	8	20	22	32	54	36	51	87	77	73	150
	F_1-X-C+P<0	21	39	60	13	32	45	38	76	114	97	126	223
	Total	60	67	127	69	85	154	138	160	298	294	276	570
	χ^2		5.37*			10.77**			22.37**			12.70**	
150	F_1-X-C+P>0	34	21	55	42	32	74	70	37	107	140	86	226
	F_1-X-C+P=0	15	11	26	30	38	68	43	55	98	95	79	174
	F_1-X-C+P<0	26	49	75	18	47	65	40	84	124	111	136	247
	Total	75	81	156	90	117	207	153	176	329	346	301	647
	χ^2		9.41**			11.92**			25.32**			13.71**	

[a] F_1 is the last trade in the futures contract that precedes the trades in the put and call options. X = exercise price, C = call option price, and P = put option price.

[b] The number of observations where the conditions on $F_1 - X$ and $F_1 - X - C + P$ are met.

[c] χ^2 is a 2 x 2 chi-square statistic calculated by comparing observations where $F_1 - X > 0$ or $F_1 - X \le 0$ with observations where $F_1 - X - C + P > 0$ or $F_1 - X - C + P < 0$.

**(*) indicates significance at the 0.01 (0.05) level.

Table IV
Test of Put-Call Parity Relationship with Futures-Style Margining

T (in seconds)		All-Ordinaries Share Price Index			90-Day Bank Accepted Bill			3-Year Treasury Bond			10-Year Treasury Bond		
		$F_1>X$	$F_1\leq X$	All	$F_1>X$	$F_1\leq X$	All	$F_1>X$	$F_1\leq X$	All	$F_1>X$	$F_1\leq X$	All
90	F-X-C+P>0[a]	16	14	30	23	16	39	41	24	65	83	83	166
	F-X-C+P=0	6	6	12	16	25	41	33	44	77	68	65	133
	F-X-C+P<0	13	28	41	12	20	32	35	55	90	99	85	184
	Total	35	48	83	51	61	112	109	123	232	250	233	483
	χ^2[c]		3.35			3.24			8.84**			0.51	
120	F-X-C+P>0	24	18	42	29	25	54	53	40	93	99	95	194
	F-X-C+P=0	9	7	16	23	32	55	40	55	95	78	72	150
	F-X-C+P<0	23	33	56	17	28	45	44	64	108	114	100	214
	Total	56	58	114	69	85	154	137	159	296	291	267	558
	χ^2		2.48			2.50			5.28*			0.21	
150	F-X-C+P>0	30	20	50	36	37	73	58	44	102	113	105	218
	F-X-C+P=0	12	8	20	29	39	68	46	59	105	96	78	174
	F-X-C+P<0	25	38	63	24	40	64	48	72	120	128	107	235
	Total	67	66	133	89	116	205	152	175	327	337	290	627
	χ^2		4.61*			1.93			6.28*			0.32	

a X = exercise price, C = call option price, and P = put option price. F_1 is the last trade in the futures contract that precedes the trades in the put and call options. Where $F_1 > X$, F_L is used to calculate F - X - C + P. Where $F_1 \leq X$, F_H is used to calculate F - X - C + P. Observations were only included where $F_H - F_L$ was less than or equal to one tick size.

b The number of observations where the conditions on F_1 - X and F - X - C + P are met.

c χ^2 is a 2 x 2 chi-square statistic calculated by comparing observations where $F_1 - X > 0$ or $F_1 - X \leq 0$ with observations where F - X - C + P > 0 or F - X - C + P < 0.

**(*) indicates significance at the 0.01 (0.05) level.

Table V
Test of Put-Call Parity Relationship with Futures-Style Margining
(Quintiles formed on the basis of F_1 - X)[a]

	All-Ordinaries Share Price Index (χ^2 = 10.51*)[b]				
Median F_1 - X	$1225	$300	0	-$300	-$1263
F_1-X-C+P>0[c]	15	11	14	7	8
F_1-X-C+P=0	6	8	5	3	4
F_1-X-C+P<0	10	12	12	21	20
N	31	31	31	31	32
Median F_1-X-C+P	0	0	0	-$50	-$45
	90-Day Bank Accepted Bill (χ^2 = 10.39*)				
Median F_1-X	$193	$72	-$24	-$108	-$239
F_1-X-C+P>0	18	21	12	11	12
F_1-X-C+P=0	12	14	16	16	10
F_1-X-C+P<0	11	7	13	15	19
N	41	42	41	42	41
Median F_1-X-C+P	0	0	0	0	0
	3-Year Treasury Bond (χ^2 = 34.12**)				
Median F_1-X	$418	$140	-$56	-$197	-$608
F_1-X-C+P>0	26	34	19	20	8
F_1-X-C+P=0	22	20	15	20	21
F_1-X-C+P<0	17	12	32	26	37
N	65	66	66	66	66
Median F_1-X-C+P	0	$141	0	0	-$142
	10-Year Treasury Bond (χ^2 = 25.85**)				
Median F_1-X	$1614	$708	$78	-$476	-$1125
F_1-X-C+P>0	47	57	51	45	26
F_1-X-C+P=0	36	36	37	33	32
F_1-X-C+P<0	46	37	41	52	71
N	129	130	129	130	129
Median F_1-X-C+P	0	0	0	0	-$73

a For the analysis presented in this table, T is set equal to 150 seconds.

b χ^2 is a 5 x 2 chi-square statistic calculated by comparing observations in the quintiles formed on the basis of F_1 - X with observation where F_1 - X - C + P > 0 and F_1 - X - C + P < 0.

c F_1 is the last trade in the futures contract that precedes the trades in the put and call options. X = exercise price, C = call option price, and P = put option price.

d The number of observations where the conditions on F_1 - X and F_1 - X - C + P are met.

**(*) indicates significance at the 0.01(0.05) level

FOOTNOTES

1. Prior to 1993, the Sydney Futures Exchange only provided "CHIT" data. These data are sourced from the written records (or "chits") filled in by the traders on the trading floor. They are not time-precise.
2. A wool futures contract and individual share futures contracts are also traded on the Sydney Futures Exchange, but futures options are not listed on these contracts.
3. Lieu (1990) and Chen and Scott (1993) provide formal proofs of this relationship. Lieu assumed deterministic interest rates, while Chen and Scott showed that the relationship holds using stochastic interest rates.
4. Very few options were priced below their intrinsic value. To examine the extent to which this occurred, an option was deemed to be priced below its intrinsic value if this was the case using both the matching futures price of the trade prior to the option trade, and the matching futures price of the trade following the option trade. For call options, the number of trades at prices less than intrinsic value for each of the four contracts were as follows: All-Ordinaries Share Price Index 30, 90-Day Bank Accepted Bills 37, 3-Year Treasury Bonds 1, and 10-Year Treasury Bonds 11. For put options, these numbers were 28, 108, 0, and 33 respectively. Across both put and call options, and across all four contracts, on only 20 occasions (out of a total of 69 746 trades) was the option price exceeded by its intrinsic value by more than $150. (Brochures provided by the Sydney Futures Exchange suggest that the transaction cost associated with buying and exercising an option, and then novating the futures position would exceed $150.)
5. This information was provided by Stephen Chambers from the Sydney Futures Exchange.
6. The minimum value for T was set equal to 90 seconds in order to achieve a reliable sample size of matching contracts.
7. To minimize the impact of outliers, only non-parametric statistics are used in this analysis.
8. Analyses were also conducted to examine whether systematic violations of the parity

relationship were associated with the time to maturity of the options. No evidence of an association was found.

9. Tables III and IV provide an analysis of a two-way partitioning of the sample based on the rank of F_1 - X. Quintiles were selected for this analysis to provide a finer partitioning of the sample. Analyses using a three-way partitioning and quartiles yielded virtually identical results and are therefore not reported.