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Index Options: The Early Evidence

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ABSTRACT

Index options became the most important traded contracts during their first year of existence. Two contracts, namely those on the S&P100 and the Major Markets Index, have a trading volume which typically surpasses the trading volume in all individual stock option contracts. In this paper, we examine the pricing of the options on the S&P100 and the Major Markets Index. Using intra-day prices, we find the options frequently violate the arbitrage boundary, put/call parity, and are substantially mispriced relative to theoretical values. Our results suggest that tests of option pricing models may be more difficult than previously realized due to nonsynchronous prices, even using "real-time" data from the exchanges.

THE FIRST U.S. INDEX option contract began trading on March 11, 1983, on the Chicago Board of Options Exchange (CBOE). The underlying index, originally called the CBOE100 but later changed to the S&P100, was specifically constructed to be used as the index for option trading. Perhaps because the index performance was similar to the S&P500 and hence many institutional portfolios, the option contract was immediately popular and has since become the listed option contract with the largest volume and open interest. Total daily volume in the S&P100 options may amount to more than 50% of all listed stock option trades.[1]

Just over a month after trading began in the S&P100 contract, on April 29, 1983, the American Stock Exchange launched option contracts on another index. This index, called the Major Markets Index (MMI), was designed to be similar to the Dow Jones Industrial Average and is constructed as a (scaled) sum of the prices of 20 major stocks. This index option contract has subsequently become very popular and has a trading volume usually second only to the S&P100 index options.[2]

Since the S&P100 and MMI option contracts are the two most heavily traded listed option contracts, they warrant further investigation. In the next section we give a brief description of the contracts; then in Section II, we include a description of the differences between index options and stock options. The

* Wells Fargo Investment Advisors, and BARRA and the University of California at Berkeley, respectively. We are grateful to Options Research, Inc., San Francisco, California, who provided our index options prices data base, and Blair Hull for advice. This research was supported by BARRA.

[1] Recent daily volume and open interest in the calls amounts to between \$2.5 to 3 billion and \$8 to 10 billion, respectively, in the underlying common stock. Equivalent figures for the puts are \$1.5 to 2 billion and \$4 to 5 billion, respectively.

[2] Recent daily volume and open interest in the calls and puts amount to between \$250 to 500 million and \$0.75 to 1.5 billion, respectively, in the underlying common stocks.

remaining sections describe the data and our tests on the boundary conditions, put/call parity, and the binomial option pricing model.

I. An Overview of the Index Option Contracts

A. The S&P100 Index Option

The S&P100 index is a capitalization weighted average of 100 major stocks whose options are traded on the CBOE. The base figure was set at 100 on January 2, 1976. The index shows a high correlation with the S&P500 and with many institutional portfolios. The contract size is set at $100 for each point of the index. In other words, when the index stands at 160, $16,000 worth of underlying stocks are controlled by a single option contract. The option contract (as indeed with most index option contracts) has cash settlement so that a writer, on being assigned an exercise of a call, delivers in cash the difference between the index value and exercise price.

B. MMI Options

The MMI is a price-weighted index of 20 major stocks. The contracts are traded on the American Stock Exchange. Both the computation of the MMI and its performance are very similar to that of the Dow Jones Industrial Average. The base was set at 100 on January 2, 1973, and the value of the contract is equal to 100 times the value of each point. On July 23, 1984, the index was adjusted to twice its previous level which caused the value of the contract to double.

II. Differences Between Index Option and Stock Option Contracts

There are four main differences between index options and stock options which may give rise to potential changes in option pricing and strategy between the two forms of contracts. These are: (i) the underlying asset is a portfolio rather than a single common stock; (ii) index options have cash settlement; (iii) the dividend stream on the index is more complex than that on a common stock; and (iv) the distribution of the underlying index may be less well approximated by the lognormal. These are discussed in further detail below.

A. Underlying Asset is a Portfolio

The mechanics of hedging with stock option contracts are both easy and very straightforward. This is not the case with index options, since the underlying security is a portfolio (namely, the index), and an investor who wishes to arbitrage between the option and the underlying assets has to follow far more complex procedures. This is particularly the case with the S&P100, where it is practically impossible to construct a portfolio to exactly reproduce the index. For example, in order to undertake an exact arbitrage, one would have to simultaneously invest in 100 stocks in the correct proportions. Even if this was possible, one would still have to account correctly for the reinvestment of dividend flows over the holding period together with the attendant transaction costs.

In practice, this arbitrage is not possible, and several techniques have been designed to construct proxy portfolios for various indices. These proxy portfolios contain a few highly liquid stocks, with asset weights chosen so that the portfolio tracks the specified index closely. Since there is no simple arbitrage between the option and the underlying index, as there is with stock options and their underlying assets, it is conceivable that arbitrage forces are not as powerful with index options and hence index options may display greater pricing errors than do stock options.

Futures contracts are traded on some optioned indices, and their existence may make the arbitrage less uncertain. However, for the two indices analyzed here this is not the case, since the futures on the S&P100 have no volume and hence cannot be used, and futures on the MMI only began trading late in 1984. Many traders use the future on the S&P500 but this introduces basis risk from the less than perfect correlation between the S&P500 and the underlying index.

The impact of the underlying index and proxy portfolio can be demonstrated as follows. Let C_t and I_t be the price of an index call and the underlying index at time t, respectively. An investor who wishes to take advantage of a perceived overpricing of the call by forming a "riskless" hedge would attempt to construct a portfolio, P_t such that $P_t = I_t$, for all t. Since this condition is practically unattainable, the portfolio at a later time τ, satisfies $P_\tau = I_\tau + \varepsilon_\tau$, where ε_τ is the magnitude of the tracking error. The investor's profit from the hedge, where the hedge ratio is Δ, over the interval $[t, \tau]$, is:

$$\begin{aligned}(\Delta P_\tau - C_\tau) - (\Delta P_t - C_t) &= (\Delta I_\tau + \Delta\varepsilon_\tau - [\hat{C}_\tau + u_\tau]) - (\Delta I_t - [\hat{C}_t + u_t]) \\ &= \{(\Delta I_\tau - \hat{C}_\tau) - (\Delta I_t - \hat{C}_t)\} + \Delta\varepsilon_\tau - u_\tau + u_t\end{aligned}$$

where $\hat{C}$ is the theoretical price of the option, and $u_t = C_t - \hat{C}_t$ is the difference between the market price and theoretical price of the call. The term in braces represents the profit from exactly arbitraging between the correctly priced options and the underlying index, and (under appropriate conditions) yields the risk-free return on capital employed. The next two terms, $\Delta\varepsilon_\tau - u_\tau$, represent the risk borne by the investor in this arbitrage strategy in order to capture mispricing u_t. The term u_τ indicates the mispricing in the option when the hedge is unwound. Of course, provided the hedge is rebalanced continuously according to the correct rules until the expiration of the option, the impact of this mispricing can be neglected. However, the tracking error, $\Delta\varepsilon_\tau$, is always uncertain and never guaranteed to vanish.[3]

B. Cash Settlement

Another major difference between index and stock contracts is that index options typically have cash settlement. As indicated above, on the exercise of an index call, the assigned writer is obligated to pay the exercising holder cash equal to the difference between the closing level of the index on the exercise date and the exercise price. Thus, when an investor exercises an option, the exact amount of cash which will be received is only known after the market has closed (and

[3] Notice that, in this example, positive tracking error gives rise to profits and not losses, suggesting that symmetric measures of risk may not be appropriate.

certainly after instructions to exercise have been delivered). In fact, it is possible to exercise an in-the-money call during the day only to find at the close that it is out-of-the-money. Moreover, the assigned writer will only learn of the exercise the next day. Even if the writer is hedged with a long position in a portfolio proxy for the index, a loss will result if prices have fallen that day.

This *timing risk* is particularly evident with spread positions where the written option may be exercised against the investor one day but the long position can only be exercised or sold to cover the next day. This means that there is some potential risk since the investor will have unhedged positions between the time that the underlying securities are closed out and the exercise of a related options position. Finally, there may be opportunities, to the extent that the market moves towards the end of the day forecast opening prices the next day, for a particular exercise strategy prior to the market closing to be beneficial. For example, if prices are rising, it may be optimal to exercise a put prior to the market close rather than the next day.

C. Dividend Stream on the Index

It is now widely known that the dividend payments on stocks have a major impact in the pricing of stock options (see, e.g., Merton [5]). The dividend stream for index options is clearly far more complex than that of an individual stock. This has offsetting impacts: first, there is much more research required in estimating an accurate dividend stream for index options. However, the resultant dividend stream for well-diversified, broad-based indices looks far more continuous than that of a stock option, and hence the probability of early exercise of index calls is diminished.

This is because early exercise of a call is optimal only if the amount of the dividend thus captured exceeds the foregone interest on the exercise price. When the underlying asset has a continuous dividend yield and the spread between yield and interest rates widens, this can only happen for increasingly deep in-the-money calls. With interest rates about double dividend yield in the period analyzed here, early exercise of any of the listed calls is highly unlikely. For puts, the situation is more complex although it appears that dividends decrease the likelihood of early exercise (see Geske and Shastri [3]).

Figure 1 shows the predicted dividend stream for the S&P100. The majority of dividends cluster around the half- and one-cent mark, and give a relatively continuous pattern. However, there are also three major dividends which cause periodic spikes.

D. Distribution of Index Returns

Most of the theoretical pricing formulas for options rely upon the fact that the underlying asset return distribution is lognormal with constant variance. For individual stocks, this assumption may be quite reasonable. However this is not necessarily the case for the MMI, which is a price-weighted index. This follows since a large return on any one asset in one period will cause a change in the composition of the index over the succeeding period. In other words, the index is likely to show significant nonstationarity in return.

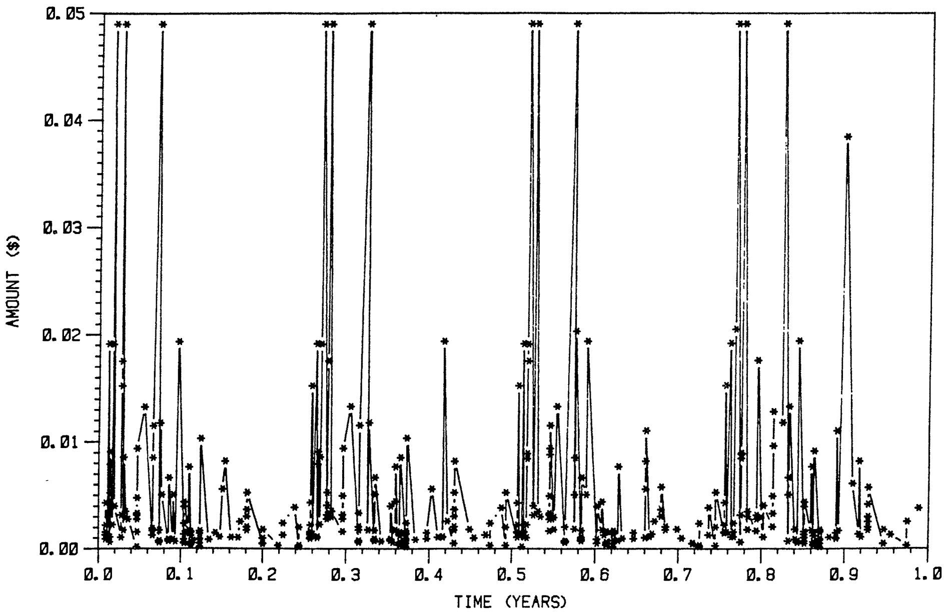

Figure 1. Predicted Dividend Stream for S&P100 as of April 29, 1983

Table I

Test of Lognormality[a]

	MMI	S&P100	Eastman Kodak	IBM	Xerox
Mean	0.988	0.032	−0.0577	0.161	0.046
Standard deviation	0.173	0.155	0.246	0.221	0.213
K-S Statistics[b]	0.110	0.063	0.082	0.077	0.076
Sample moments					
Mean	−0.18	0.00	−0.06	−0.02	−0.03
Standard deviation	0.88	1.01	1.05	0.99	1.00
Skewness	−0.50	0.118	−0.76	0.01	−0.15
Kurtosis	2.41	3.626	4.31	3.15	2.83

[a] Based on 85 daily prices: May 1, 1983–August 30, 1983.
[b] Significance levels: 99% = 0.179; 95% = 0.150.

We attempted to test the hypothesis that the index returns are lognormally distributed with a constant variance. Parameters for the drift and volatility were fitted using a maximum-likelihood method assuming that volatility over holidays and weekends were equivalent to one day.[4] We used a sample of 85 daily closing prices from May 1, 1983 through August 30, 1983. These results are shown in Table I and are compared with the equivalent tests for three major stocks, Eastman Kodak, IBM, and Xerox. A casual observation of the sample moments

[4] The differences in volatility between periods when the market is open and when it is closed has been the subject of much recent academic research (see, e.g., French and Roll [2]).

of the fitted underlying $N(0, 1)$ distribution seems to suggest that the S&P100 index is not very different from the moments of the individual stocks. However the MMI does show some slight differences from lognormality. This observation is reinforced somewhat by the Kolmogorov-Smirnoff statistic, which measures the maximum absolute value of the difference between the fitted distribution function and the hypothesized "true" distribution function. The statistic is higher for the MMI than for either the three stocks or the S&P100. However, it is not significant even at the 5% level, and hence we cannot reject the hypothesis.

III. Data

A. Prices

Our database of prices was captured from a real-time pricing service. Rather than analyzing every trade (which would have been far too numerous), we captured prices corresponding to the most recent trade prior to set times (mostly on the hour). Each day we captured six "cross-sections" or "snapshots" of market conditions. Each snapshot contained essentially the same information as would be displayed at the screens on the exchange floor. In this manner, we captured the last trade, volume of last trade, current bid/ask spread, and current underlying index value. Thus, our data suffers from the same asynchronous pricing between the last option trade and current index value as on the exchange floor. Moreover, it is possible that the current spread and current index value also may not be perfectly synchronous.[5] The S&P100 (and S&P500) index spot prices are updated approximately once a minute from the exchange tape, however the bid/ask spread is obtained from quote reporters trying to monitor a large crowd (in a possibly fast moving market). Interestingly, the S&P500 futures prices, which were not part of our database but are available on the floor, are also updated from exchange tapes, but large firm traders have a timing edge by virtue of private communication lines between the two floors.

Our data started on June 26, 1984 and ended on August 30, 1984. Unfortunately, at various times during the period, some data points are missing. Figures 2 and 3 show the performance of the underlying indices.

There were a total of 1798 observations for the following contracts, distributed as shown below.[6,7]

[5] "Real-time" prices come in one of two forms: either direct from the exchanges (*direct feeds*) when the delay is essentially zero, or from vendors who accumulate the direct feeds from several exchanges into one transmission (*digested feed*). In this latter case, there may be a delay of three minutes (or longer on days with heavy volume) between the exchange and receipt of the data. More problematic is that the process of "digestion" may induce some nonsynchronous pricing as the feeds are aggregated.

[6] We also captured data on September and October contracts, although these are not analyzed here.

[7] As indicated previously, the MMI was adjusted on July 23 to become twice as large; i.e., the August 110 became the August 220. We retain the original name of the contract for consistency.

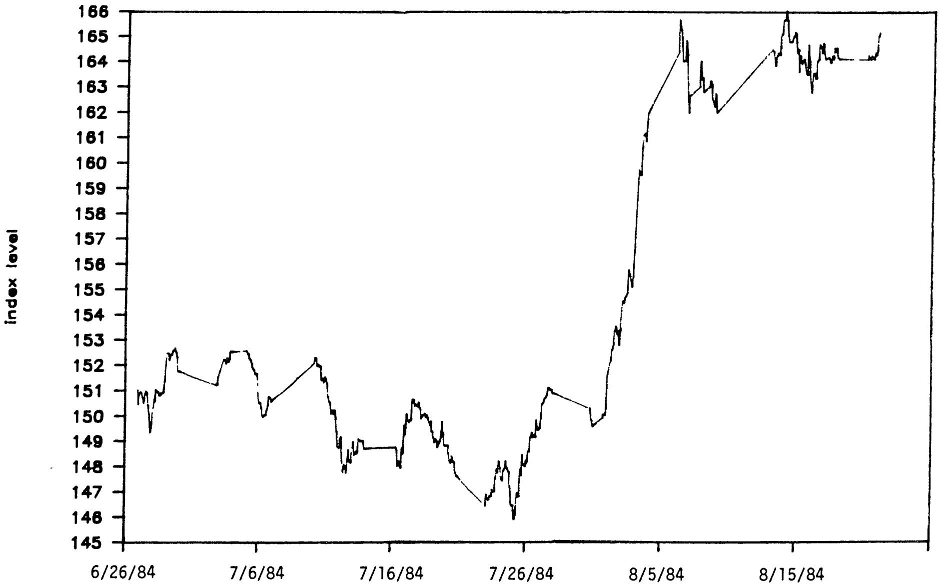

Figure 2. S&P100 Index Level

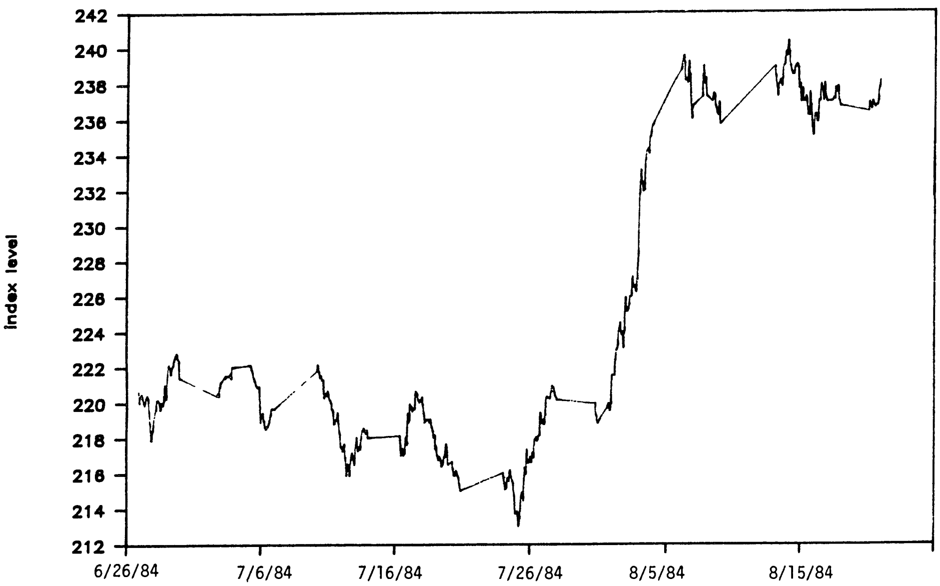

Figure 3. MMI Index Level

Contract	Observations
S&P100	
August 145	366
August 150	362
August 155	363
MMI	
August 110	349
August 115	358
Total	1798

B. Interest Rates

We used the 90-day Treasury bill rate, adjusted for the maturity of the option. Although not theoretically correct, we feel the errors induced by this approximation are minimal.

C. Dividends

We used predicted dividends for each of the stocks comprising the indices. These predictions were based on a model developed at BARRA to estimate dividends on a stock-by-stock basis accounting for the seasonality and growth in payments and the timing of the ex-dividend dates.

IV. Tests of Option Lower Boundary

The basic lower pricing condition for American call options is that the call asking price should be nonnegative and no less than the underlying index price; i.e., $C_{at} \geq I_t - K$, where C_{at} is the call/ask price at time t. In theory, if this bound is violated, arbitrage profits could be made by purchasing the call and selling the index. However, as indicated previously, the act of selling the index requires the simultaneous short selling of several stocks, which is difficult to accomplish.[8]

We tested the lower bound condition, and the results are given in Table II. We observed 41 occasions where the call asking price was less than the intrinsic value of the option. Thirty observations were related to the S&P100 and 11 to the MMI; all occurred between August 1 and August 6.

The number and sizes of these violations is surprising. Certainly, the difficulty of the arbitrage is partly the reason for these violations. However, the size of the violations on the MMI occasionally became so large that even "upstairs traders" would have been able to take advantage. For example, on August 3 at approximately 10:30 A.M., when the index was at \$231.81, the August 220 (which we refer to above as the August 110) was trading at \$10.75. In other words, the violation was \$1.06!

[8] As explained above, purchasing the call and then immediately exercising it is not riskless since the relevant index value is its value at the close.

Table II

Call Lower Bound Violations

	Violation		
Contract	No. Observed	\$Mean	Std. Dev.
S&P100			
Aug. 145	16	0.22	0.14
Aug. 150	9	0.29	0.13
Aug. 155	5	0.07	0.03
MMI			
Aug. 110	11	0.48	0.36
Aug. 115	0		

Table III

European Put/Call Parity Violations

	Call Underpriced			Call Overpriced		
Contract	No. Observed	\$Mean	\$Std. Dev.	No. Observed	\$Mean	\$Std. Dev.
S&P100						
Aug. 145	241	0.45	0.31	39	0.11	0.08
Aug. 150	264	0.54	0.34	35	0.12	0.08
Aug. 155	293	0.66	0.36	42	0.15	0.10
MMI						
Aug. 110	40	0.26	0.25	208	0.27	0.24
Aug. 115	97	0.33	0.35	79	0.28	0.21

A more likely explanation for the large reported violations is that because of the dramatic increase in the market during this week, the index values were being updated more frequently than the bid/ask spreads. This shows up a possible limitation of all data capture systems, including "real-time" prices direct from the exchanges. It also points out that traders on the floor have a distinct competitve advantage over traders and investors off the floor.

V. Tests of European Put/Call Parity

The dividend stream on an index is more continuous than on an individual stock and so the occasions when index options may be exercised are reduced, although not eliminated. Index options may therefore appear to behave as European rather than American. We tested the European put/call parity relationship:

$$C_{bt} \leq P_{at} + I_t - Ke^{-r(T-t)} - \textstyle\sum_{\tau=t}^{T} d_\tau\, e^{-r(\tau-t)}, \quad \text{for all } t$$

$$C_{at} \geq P_{bt} + I_t - Ke^{-r(T-t)} - \textstyle\sum_{\tau=t}^{T} d_\tau\, e^{-r(\tau-t)}, \quad \text{for all } t$$

where C_{at}, P_{at}, C_{bt}, and P_{bt} are the call, put/ask and bid prices, respectively, and d_t is the dividend payment stream at time t.

The results shown in Table III indicate that if index options are treated as European, there are significant potential profit opportunities. Qualitatively, the

S&P100 calls are underpriced (puts are overpriced), with the reverse being true for the MMI options.

VI. Tests of American Put/Call Parity

The version which we tested holds when interest rates and dividends are known, and is given by (see, e.g., Jarrow and Rudd [4]):

$$C_{bt} \leq P_{at} + I_t - L, \qquad \text{for all } t,$$

$$C_{at} \geq P_{bt} + I_t - K - \textstyle\sum_{\tau=t}^{T} d_\tau\, e^{-r(\tau-t)}, \quad \text{for all } t,$$

where

$$L = \min_{T\geq\tau\geq t}[Ke^{-r(\tau-t)} + \textstyle\sum_{l=t}^{\tau} d_l\, e^{-r(l-t)}].$$

In other words, L is the present value of the cash flow resulting from exercise at any time, τ, prior to expiration.

The results in Table IV show that even when considered as American options, there are a significant number of potential profit opportunities. These results also reinforce the qualitative result that the S&P100 and MMI options appear to be valued differently.

The S&P100 call underpriced violations occurred almost entirely (58 of 61) during the market advance between August 1 and August 6. Hence, these violations may have been spurious in the sense that the prices displayed on screens at the exchange may not have been perfectly synchronous.

In contrast, the call overpricing violations for both the S&P100 and MMI occurred throughout the period. Intriguingly, the MMI contract displayed a greater number of overpricing violations than did the S&P100 contract. To take advantage of the overpricing, the call is written while the put and the index are purchased. Hence, this arbitrage is practically quite easy, since there is no need to sell short many stocks in the index proxy portfolio. Moreover, the S&P100 overpricing violations are exactly the same as those reported for the European put/call parity tests (see Table III), while those for the MMI are different. This suggests that there is value associated with the early exercise feature of MMI calls but not S&P100 calls, which is consistent with the more continuous dividend pattern of the S&P100.

Table IV

American Put/Call Parity Violations

	Call Underpriced			Call Overpriced		
Contract	No. Observed	$Mean	$Std. Dev.	No. Observed	$Mean	$Std. Dev.
S&P100						
Aug. 145	10	0.11	0.08	39	0.11	0.08
Aug. 150	21	0.17	0.10	35	0.12	0.08
Aug. 155	30	0.29	0.18	42	0.15	0.10
MMI						
Aug. 110	1	—	—	133	0.22	0.18
Aug. 115	1	—	—	65	0.29	0.20

These results are in contrast to those we obtained in an earlier test, which was based on closing prices for the period April 29, 1983 through September 6, 1983 (Evnine and Rudd [1]).

In this earlier period, the MMI calls and puts appeared correctly relatively valued within the arbitrage bounds, while the S&P100 calls (puts) were relatively under(over) valued. One explanation, which is consistent with these two different sets of results, is that the options go through relatively long "cycles" of over- and undervaluation. Alternatively, there may be bias resulting from the use of closing prices rather than intra-day prices.

VII. Intra-day Patterns

Traders in the market have observed that the implied volatility of index options changes throughout the day. In particular, that implied volatilities are highest shortly after the open of the market and then decrease throughout the day to their lowest point shortly before the close. These casual observations have engendered a popular strategy; straddles or strangles[9] are sold early in the morning and purchased back towards the close.

These intra-day changes could also be responsible for our observations that put/call parity using closing prices in our first sample period had qualitatively different characteristics from put/call parity results using intra-day prices in our second period. Succinctly, are index option closing prices representative of prices observed earlier in the trading day?

We attempted to test this hypothesis by computing the implied volatility of the short maturity at-the-money calls at our first (very close to the open) and last (closing price) observations of the day. We pooled these implied volatilities across the 63 days, and a nonparametric sign test was run on the difference. Perversely, the signs were split almost exactly evenly. The difference was computed, and under the assumption of normality, a t-statistic for the mean computed; this was found to be virtually zero. The tests were rerun for several other pairs of time points, and no difference was ever found.

The results fail to confirm the traders' observations: we could detect no intraday pattern to the implied volatilities. Moreover, our tests do not lead one to reject the hypothesis that closing prices are representative of option prices recorded throughout the day.

VIII. Tests of the Binomial Option Pricing Model

It is notoriously difficult to test theoretical option pricing models (see, e.g., Rubinstein [6]). Not only is the volatility unobservable (and possibly nonstationary), but also there are the familiar problems of nonsynchronous pricing. In effect, most tests of the theoretical models become joint tests of several hypotheses.

Our approach has been to test a less powerful hypothesis in a more direct manner. This hypothesis states that the binomial option pricing model is the

[9] A position composed of a put and call with the same maturity and underlying asset but with exercise prices to either side of the current underlying asset price.

Table V

Option Mispricing

	MP_1		MP_2		MP_3	
	$Mean	$Std. Dev.	$Mean	$Std. Dev.	$Mean	$Std. Dev.
S&P100						
All puts	4.46	30.14	0.19	0.33	4.26	37.11
OTM puts	6.32	34.20	0.16	0.24	5.87	42.41
ITM puts	0.21	0.60	0.18	0.47	0.04	0.10
All calls	0.07	0.45	−0.03	0.11	0.09	0.24
OTM calls	0.26	1.01	0.00	0.15	0.19	0.51
ITM calls	−0.08	0.29	−0.07	0.26	0.00	0.04
MMI						
All puts	−0.19	1.82	−0.17	0.37	0.10	0.67
OTM puts	0.01	2.95	−0.12	0.28	0.26	1.58
ITM puts	−0.62	1.00	−0.40	0.64	−0.05	0.08
All calls	−0.20	0.77	−0.07	0.51	−0.02	0.09
OTM calls	−0.39	0.61	−0.10	0.16	−0.08	0.29
ITM calls	0.17	0.29	0.15	0.25	0.02	0.03

correct index option pricing model relative to the short at-the-money call options. In other words, we force the binomial model to fit exactly the short at-the-money call, and then use the resulting implied volatility to value the remaining calls and puts.[10]

This test will display biases in each cross-section of prices. However, it will not substantiate whether options as a group are priced correctly in absolute magnitude. For example, if calls on average are overpriced, then our test would not have demonstrated any mispricing.

At each "snapshot," the shortest maturity (provided it had at least 14 days until maturity) call with exercise price within $2.50 of the index level was designated the short at-the-money call. The implied volatility of this call was computed and then used to value the remaining calls and puts. The designation of in-the-money and out-of-the-money was used for options whose exercise prices were $2.50 or more away from the index value.

Each call was then valued using the binomial model, and three mispricing measures computed:

$$MP_1 = (W - V)/|\Delta|; \quad MP_2 = W - V; \quad MP_3 = (W - V)/V$$

where W is the average of the option bid/ask prices, V the theoretical option price, and Δ the option delta. In essence, MP_1 represents the risk (delta) adjusted mispricing, MP_2 the average mispricing, and MP_3 the proportional mispricing. Finally, within the classifications (in-the-money, out-of-the-money, and all options), we volume-weighted the mispricing measures to remove the impact of possibly spurious mispricings caused by thin trading (Table V).

[10] In fact, for computational reasons, we used the volatility from a dividend adjusted Black-Scholes formula to compute the implied volatility. We then valued the short at-the-money call using the implied volatility in the binomial model to verify that the implied volatility was indeed the correct one.

Notice that the MP_1 and MP_3 measures may become large, particularly when the denominator is small, such as for deep out-of-the-money options. This is evident in fast-moving markets when "old" prices cause substantial errors in the numerator. We tested for this effect by recalculating the statistics, leaving out the week when the market had the dramatic increase. The means and standard deviations of the errors were reduced for the S&P100 puts. However, the S&P100 calls and MMI options showed little change, as did the MP_2 statistics.

As is evident from the results, the S&P100 and MMI options are priced differently, but both option contracts have economically significant pricing errors. The S&P100 puts are overpriced relative to the short at-the-money call, with the out-of-the-money puts being more overpriced (both proportionally and risk-adjusted) than in in-the-money puts. On average, the calls are relatively correctly priced.

The MMI options on the other hand have different characteristics. On average, the puts appear underpriced, although there were a few high-volume out-of-the-money puts that were substantially overpriced. Moreover, the out-of-the-money calls appear cheap and in-the-money calls expensive relative to the at-the-money call.

IX. Summary

In general, our results show there are significant violations of the arbitrage condition and put/call parity. Even acknowledging the difficulty of earning risk-free (or close to risk-free) profits from the violations because of either the need to construct a proxy portfolio to trade the index or the lack of the correct future contract, the violations which we observed are substantial. Moreover, we observed substantial deviations between market prices and theoretical prices derived from the binomial option pricing model.

These results suggest that the market is inefficient to some degree (which at first may seem somewhat implausible given the sophistication and daily volume in these markets). It is likely that much of this inefficiency may be induced by the inability of investors to arbitrage the index options at low risk.

Finally, it is also likely that our database, although captured from real-time prices, displays a degree of nonsynchronous pricing. We believe that it is inevitable that even real-time prices direct from exchanges will be somewhat nonsynchronous. Our results suggest that in calm markets the errors induced by nonsynchronous pricing may not be too severe. However, under hectic trading conditions, as for example in the first week of August during the dramatic market upturn, it appears that trading can outpace the collection capabilities of the quote reporters and pricing tapes.

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DISCUSSION

JAMES D. MACBETH*: The authors have done a good job in explaining the properties of these new financial instruments. Their data analysis is rigorous, and I concur with their conclusions. Our option valuation models do not explain all that is going on in the market place.

It is of interest to note that the nature of the mispricing of index options has been consistent with the nature of mispricing of futures contracts on the S&P500 Index. From April 1983 to September 1983 S&P100 calls appeared to have been overpriced relative to puts. During this period, S&P500 futures contracts were underpriced relative to the S&P500 index (given a tax-free environment). This type of mispricing provided an opportunity for equity indexers to outperform the index with a long position in calls (and bills) coupled with a short position in puts, in the case of the S&P100 index, or a long position in futures (and bills), in the case of the S&P500 index. In the last half of 1983, numerous indexers took advantage of these opportunities, very often with tax-exempt pension fund dollars. It is not clear that indexers necessarily caused a reversal of the mispricing but for some reason the nature of the mispricing of futures contracts changed in the last quarter of 1984. In 1984, S&P100 calls have been underpriced relative to puts, and S&P500 futures have been overpriced relative to the index. I speculate that this type of mispricing has persisted because investors who could easily exploit it are those who wish to hedge their equity investments. From casual observation of the financial press, I conclude that there are not a lot of these investors around. I find it encouraging to observe some consistency in the shortcomings of our valuation models across different financial instruments.

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