# FURTHER EVIDENCE ON PARITY RELATIONSHIPS IN OPTIONS ON S&P 500 INDEX FUTURES

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## INTRODUCTION

Empirical tests of option-pricing-model adequacy and options-market efficiency characteristically attempt to identify riskless opportunities for excess trading profits by analyzing trading strategies defined by either absolute-valuation or relative-valuation (e.g., put–call parity) models. However, tests to identify mispriced options and excess profits utilizing either model approach inherently encompass a joint test of model adequacy and market efficiency. Since the integrity of empirical results depends upon the precision with which actual market conditions are replicated, the empirical test design must independently evaluate the efficiency of the market under analysis.

To circumvent the problems inherent within these approaches, this study employs the box-spread arbitrage model to evaluate the efficiency of the market for S&P 500 Index futures-options. The box-spread parity

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relationship facilitates a test of options-market efficiency independent of absolute-valuation-model input requirements, and as a result, the model should provide more credible results. Billingsley and Chance (1985) utilize this relative-valuation approach in an examination of stock-option-market efficiency, finding that box spreads constructed using options on individual stocks fail to generate persistent arbitrage profits during the 1983 sample period. Chance (1987) also employs the box-spread model to evaluate the efficiency of the market for S&P 100 Index options. In the study, Chance constructs box spreads during a 1984 sample period and finds that significant arbitrage profits cannot be realized on a consistent basis as the positions adhere to the theoretical parity relationship. Ronn and Ronn (1989) also use the box-spread parity relationship to test the efficiency of the market for individual CBOE stock options over a sample period from 1976–1984. Using several designated per-unit estimates of transactions costs, Ronn and Ronn provide evidence that only market-makers can generate persistent arbitrage profits using the box-spread strategy.

To increase the accuracy of adjustments for transactions costs, a modified Bhattacharya (1983) price-pattern-recognition procedure is utilized in this study to categorize bid and ask futures-option prices from CME intra-day data on S&P 500 futures-options and to adjust the box-spread positions for transactions costs. Nonparametric test results indicate that the cost-adjusted spreads are significantly unprofitable, and the degree of dispersion in spread returns accordingly increases as the time interval required to effect the composite position is permitted to expand. The results emphasize the impact of bid–ask spreads and increasingly nonsynchronous price observations on box-spread returns and the corresponding effects on tests of market efficiency.

## DATA

Provided by the Chicago Mercantile Exchange, the data utilized in this study consist of both transaction prices and quoted bid and ask prices from the trading of options on S&P 500 Index futures contracts. The data represent all intra-day price quotes recorded on these contracts for the sample period of January 28, 1983 through June 30, 1992, during which time options on 42 separate S&P 500 Index futures contracts were traded at the Index and Option Market Division of the Chicago Mercantile Exchange.[1]

[1] During the sample period, contracts analyzed in this study include S&P 500 Index futures-options maturing in the contract months of March, June, September, and December for the years 1983 through 1992.

These data comprise recorded transactions as well as market-maker bid and ask quotations for which no transaction actually occurred. Accompanying each quoted price is the date and the time of day at which it occurred, but the motivation of the market-maker for transaction prices is unavailable from this data base. Since transaction prices cannot be immediately distinguished as either bid or ask transactions, a modified Bhattacharya technique is used because the box-spread arbitrage model requires categorized transaction prices to adjust spread returns for transactions costs. The transaction prices and the timed, intra-day bid and ask quotes enable the construction of nearly simultaneous positions in S&P 500 futures-options. The capability to construct nearly synchronous option positions should facilitate an evaluation of spread returns and market efficiency without exposing the test design to biases arising from the use of nonsynchronous data.

# METHODOLOGY AND EMPIRICAL RESULTS

## The Box-Spread Arbitrage Model

A box spread is an option strategy designed to capitalize upon relative pricing inefficiencies between four separate options written on a single underlying asset using two exercise prices. A long box spread is constructed by the contemporaneous combination of a bull call vertical spread and a bear put vertical spread, while a short spread simultaneously combines a bear call vertical spread and a bull put vertical spread. A summary of the respective vertical spread positions is provided in Table I.

Since futures-options are exclusively utilized in the box-spread arbitrage relationship, the box-spread model assumes no position

**TABLE I**

Summary of Vertical Spread Positions

| | | *Position*[a] | |
|---|---|---|---|
| *Strategy* | *Type* | $E_1$ | $E_2$ |
| Bull | Call | Long | Short |
| Bear | Put | Short | Long |
| Bear | Call | Short | Long |
| Bull | Put | Long | Short |

[a]The positions listed represent the positions concurrently assumed in the respective options at the lower exercise price ($E_1$) and at the higher exercise price ($E_2$), respectively. The combined vertical strategies in each box-spread position are constructed using only two exercise prices, collectively.

in the futures contract underlying the four options, thereby eliminating the structural design problems associated with interim payments characteristic of put–call–futures–parity tests. The existence of two different exercise prices indicates that the futures price of the underlying S&P 500 Index at maturity may lie below both exercise prices, between the two exercise prices, or it may exceed both exercise prices.[2] An examination of the returns realized within the three possible ranges of the S&P 500 Index futures price at maturity reveals that, in the absence of transactions costs, the consolidated strategy yields a value of $(E_2 - E_1)$ at expiration of the options, irrespective of the index futures price. Because of this certain outcome, the resultant box spread represents a theoretically riskless strategy prior to any adjustment for transactions costs. Therefore, under the assumptions of (1) market efficiency, (2) accurately priced futures-options, (3) no early exercise, and (4) deterministic interest rates, the box spread should yield the riskless rate of return, and its current market value should equal the present value of the exercise-price spread discounted at the continuously compounded, riskless rate of return:

$$V_0 = (E_2 - E_1)e^{-rt} \qquad (1)$$

where:

$V_0$ = market value of the box spread at initiation,
$r$ = riskless rate of return, and
$t$ = time to expiration expressed as a fraction of a 365-day year.

With respect to potential deviations from the parity relationship, the composite position would generate less than the riskless rate of return if the current market value of the box spread exceeds the present value of the payoff. Conversely, if the current market value of the box spread is less than the present value of the payoff, the position would produce a return in excess of the riskless rate of interest. The persistence of either situation, after accurately adjusting for transactions costs, would provide evidence of market inefficiency. However, before excess spread returns can be accepted as evidence of futures-option market inefficiency, the structural design of the study must ensure that actual market conditions are replicated as precisely as possible. This empirical requirement necessitates a consideration of operational constraints, particularly the impact of transactions costs and the possibility of early exercise.

[2]See Ronn and Ronn (1989) for a comprehensive analysis of the box-spread arbitrage conditions.

## Early Exercise and Box-Spread Model Construction

In the pricing of futures-options, numerous restrictive, arbitrage-based assumptions must be satisfied to determine theoretical values. One particular theoretical assumption violated as a matter of course under actual market conditions involves the type of options traded on the exchanges. The theoretical box-spread arbitrage model assumes that only European options comprise the spread, thereby implicitly assuming the construction of a buy-and-hold spread to be held until expiration of the options. Since virtually all options and futures-options traded in the United States are American contracts, either the calls or the puts may be rationally exercised early, although Brennan and Schwartz (1977) indicate that the early exercise of American puts rarely occurs.

In the construction of box spreads, the risk of early exercise is greater for short spreads than for long spreads. The risk to the long box-spread holder is minimal since the respective short positions in the bull call (written at $E_2$) and the bear put (written at $E_1$) spreads represent the option positions of lower relative values in the respective vertical spreads, so the long call (put) will be deeper-in-the-money at any time the short call (put) is in-the-money. Consequently, if conditions arise that would provoke the rational early exercise of the short call (put) in a box spread, such as a precipitous increase (decrease) in the index futures price above (below) the higher (lower) exercise price, the composite position would produce a net cash inflow of $(E_2 - E_1)$, plus the positive difference in option premia realized from liquidating the out-of-the-money put (call) positions. A box spread, under these conditions, would generate the riskless return over a shorter time interval of the spread is accurately priced when constructed.

In a short box spread, however, the reversed option positions produce a net initial cash inflow, followed by a net cash outflow at expiration because the respective short positions in the bear call (written at $E_1$) and the bull put (written at $E_2$) spreads represent the more valuable option positions in the respective vertical spreads. If rational early exercise of the short call (put) is induced by an increase (decrease) in the index futures price above (below) the lower (higher) exercise price, the short call (put) would be deeper-in-the-money than the long call (put) and the composite position would produce a composite cash *outflow* equivalent to the exercise-price spread, $(E_1 - E_2)$, plus the negative difference in premia realized from the liquidation of the put (call) positions. By assuming long positions in the futures-options with lower relative values, the short box-spread arbitrageur, unlike the long-spread holder, cannot negate the detrimental effects of rational early exercise and is unhedged against the significant risk of loss from the possibility of early exercise.

As a consequence, the risk of loss associated with the early exercise of futures-option positions is significantly greater for short box spreads than for long spreads. However, while the possibility of early exercise is an important practical consideration, of greater theoretical importance is the integrity of the empirical test design. The primary advantage of employing the box-spread model in tests of market efficiency lies in its certain outcome, regardless of the price of the underlying futures contract, assuming that the spread remains intact until option expiration. Permitting the early exercise of any futures-option included in a box spread without simultaneously liquidating the remaining three option positions would violate the theoretical constraints upon which the box-spread arbitrage conditions are founded. Early exercise of a futures-option and the noncontemporaneous liquidation of the remaining option positions would expose the box-spread arbitrageur, particularly the short-spread holder, to considerable *speculative (or legging) risk* if the futures-option positions cannot be liquidated simultaneously, or at least within a *reasonable* time interval (defined as the same time interval originally required to construct the spread). The presence of legging risk, which is analogous to the risk associated with the noncontemporaneous construction of spreads, could potentially bias the empirical analysis toward a conclusion of market inefficiency if sample box-spread returns include a premium to compensate for legging risk.[3] Therefore, since 94% of the spreads constructed cannot be completely liquidated within reasonably designated time intervals, this study exclusively analyzes long box spreads, held to futures-option expiration, to minimize the impact of early exercise on the empirical results.

## Transactions Costs and the Bid–Ask Spread

Phillips and Smith (1980) assert that efficiency studies testing for realizable arbitrage profits must accurately adjust for transactions costs, and the failure to satisfy this requirement can produce inaccurate test results. According to Phillips and Smith, the failure to account for the unobservable, implicit transactions costs, represented by the

[3]For example, see Sofianos (1993) for a description of the effects of legging risk in the cash and futures markets.

bid–ask spread of the market-maker, constitutes a "selection bias" toward a conclusion of market inefficiency. However, the absence of an immediate bid–ask categorization of transaction prices in available data makes accurate testing difficult. As a result, several procedures have been devised to impute the bid–ask spread from observed price data.

Roll (1984) derived a measure to estimate the bid–ask spread for stock and option markets that assumes that buy and sell orders arrive randomly in a trendless market. However, trading noise can produce positive serial correlations and consequently cause a downward bias in the estimated bid–ask spread generated by the Roll measure.[4] Relaxing the assumption of serial independence between price changes, Choi, Salandro, and Shastri (1988) assumed that oscillations between bid and ask prices are not random. As a result, Choi, Salandro, and Shastri estimated the value of the probability measure through an iterative process using a maximum likelihood procedure, but this technique may identify a local optimum rather than the global optimum with an inaccurate initial estimate of the bid–ask spread.

In an alternative approach, Bhattacharya (1983) devised a procedure designed to identify the motivation underlying undesignated transaction prices. The Bhattacharya approach examines alternating price movements that are opposite in sign to the immediately previous price change. Assuming that traders can purchase only at market-maker ask prices and sell only at market-maker bid prices (to minimize selection bias), the Bhattacharya technique characterizes a bid (ask) price as a down-tick (up-tick) transaction price surrounded by up-tick (down-tick) prices.

To illustrate the unmodified Bhattacharya methodology, consider the nine price records provided in Table II and based upon Table A.1 in Bhattacharya (1983). According to the Bhattacharya procedure, records 1, 2, and 3 represent bid, ask, and bid prices, respectively, based on the price-change pattern of $+\frac{1}{8}$ and $-\frac{1}{8}$ between the records. A similar pattern exists between records 3, 4, 5, and 6, given the consecutive price changes of $-\frac{1}{8}$, $+\frac{1}{8}$, and $-\frac{1}{8}$, again representing bid, ask, and bid prices, respectively, for records 4, 5, and 6. However, price record 3 is common to (or overlaps) both of the price series, so ambiguity exists concerning the true motivation underlying the price quote since it could

[4] Ohlson and Penman (1985), Jordan and Seale (1986), Karpoff and Walkling (1988), Stoll (1989), and Harris (1990) find that the Roll measure may inaccurately estimate the bid–ask spread for individual securities using either intra-day, daily, or weekly data. The fundamental implication of these studies is that the Roll measure can produce negative bid–ask spreads in the presence of positive serial correlations.

**TABLE II**
The Unmodified Bhattacharya Technique

| *Record Number* | *Stock Price* | *Price Change* | *Transaction* | |
|---|---|---|---|---|
| | | | *Tick* | *Type* |
| 1 | $19\frac{5}{8}$ | | | bid |
| 2 | $19\frac{3}{4}$ | $+\frac{1}{8}$ | up | ask |
| 3 | $19\frac{5}{8}$ | $-\frac{1}{8}$ | down | bid/ask |
| 4 | $19\frac{1}{2}$ | $-\frac{1}{8}$ | down | bid |
| 5 | $19\frac{5}{8}$ | $+\frac{1}{8}$ | up | ask |
| 6 | $19\frac{1}{2}$ | $-\frac{1}{8}$ | down | bid |
| 7 | $19\frac{3}{4}$ | $+\frac{1}{4}$ | up | ask |
| 8 | $19\frac{5}{8}$ | $-\frac{1}{8}$ | down | bid |
| 9 | $19\frac{3}{4}$ | $+\frac{1}{8}$ | up | ask |

represent a bid price in the previous stream (with its associated ask at $19\frac{3}{4}$) or an ask price in the subsequent stream (with its associated bid at $19\frac{1}{2}$). Since the technique retains only non-overlapping, consecutively reverting price series of three or more records for analysis, records 1–3 are discarded from the sample. The deletion of records 1–3 leaves two possible streams, each consisting of three non-overlapping, reverting prices. The first stream categorizes record 4 as a bid price at $19\frac{1}{2}$, record 5 as an ask price at $19\frac{5}{8}$, and record 6 as a bid price at $19\frac{1}{2}$. In the second stream, record 7 is identified as an ask price at $19\frac{3}{4}$, record 8 as a bid price at $19\frac{5}{8}$, and record 9 as an ask price at $19\frac{3}{4}$.

However, based on the pattern-recognition scheme, the unmodified Bhattacharya approach could inaccurately identify either bid or ask transactions. For example, the technique identifies record 1 as a bid price for the price series of 1, 2, and 3. Without knowledge of the price quote preceding record 1, however, record 1 may actually represent an ask price for the previous series. In this study, to avoid the possibility of incorrectly identifying a price quote in this manner, and to mitigate the possibility that price patterns could result from new information rather than from movement between market-maker bid and ask prices [see Ma, Peterson, and Sears (1992)], up-tick (down-tick) transactions must surround the categorized bid (ask) transaction price used in a box-spread position and preceding and succeeding transactions must each occur within ten minutes of the categorized transaction. The ten-minute certification constraint preceding and succeeding each transaction price used in the construction of box spreads reduces the possibility of, and the effect from, significant price movements within each qualifying series.

Further, as Ma, Peterson, and Sears (1992) indicate, transaction price data can be characterized by unequal price movements and significantly positive serial correlation between price changes, conditions which cause the Bhattacharya measure to underestimate wider bid–ask spreads for "occasional transactions" that occur within the bid–ask spread of the market-maker. This study consequently requires that the non-overlapping transactions in each qualifying series successively revert in equal magnitudes to circumvent the possibility of inaccurately identifying the motivation underlying the transaction. This specific restriction forces the deletion of significant available data, a condition which can induce mispricing signals and cause hedge portfolios to remain open for excessive periods of time. However, the imposition of the aforementioned ten-minute constraint serves to negate the potential effect on bid–ask spreads caused by new information arriving in the market.

Since the Bhattacharya procedure categorizes transaction prices as either bid or ask prices, the approach facilitates a cost-adjusted analysis of box-spread performance using bid and ask futures-option prices. Therefore, with the specified modifications, the technique is used in this study to construct box-spread positions adjusted for transactions costs resulting from bid–ask spreads.

## Nonparametric Tests of Box-Spread Profitability

Galai (1977) indicates that studies using nonsynchronous, closing-price data often report the availability of excess, riskless profits and offer these findings as evidence of market inefficiency; but, such returns may actually represent imaginary, "paper" profits resulting from the use of nonsynchronous prices. This study utilizes timed, intra-day futures-option data to identify nearly contemporaneous call and put futures-option prices collectively quoted within time intervals ranging from zero to five minutes. Futures-option price quotes, including both transaction prices and quoted bid and ask prices, that occur on the appropriate side of the bid–ask spread are subsequently combined into box spreads to examine deviations from the theoretical parity relationship by an amount in excess of the bid–ask spread. Price groups failing to conform to the transactional pattern for box-spread construction are systematically discarded.

The arbitrage pricing principles that underlie the relative call and put futures-option values indicate that, theoretically, the current market value of a box-spread parity relationship should be represented by eq. (1) prior to any adjustment for transactions costs. As an operational model, however, any exploitable deviation from the parity relationship must exceed transactions costs to generate realizable profits. Only the persistent presence of such cost-adjusted deviations would provide sufficient evidence of market inefficiency.

To measure the performance of each box-spread position, excess dollar returns are computed utilizing the quoted ask yield on a U.S. Treasury Bill whose maturity corresponds to the expiration of the S&P 500 futures-option. For each long box spread, therefore, excess dollar returns are computed as:

$$\begin{aligned} R_{BS} = {} & C_{2B} + P_{1B} + [\mathrm{MAX}(0, F_T - E_{1C}) + \mathrm{MAX}(0, E_{2P} - F_T)]e^{-rt} \\ & - C_{1A} - P_{2A} - [\mathrm{MAX}(0, F_T - E_{2C}) \\ & + \mathrm{MAX}(0, E_{1P} - F_T)]e^{-rt} \end{aligned} \tag{2}$$

where:

$R_{BS}$ = excess dollar return on a long box spread,
$F_T$ = price of the S&P 500 futures index at expiration of the futures-options,
$T$ = time of expiration of the futures-options,
$C_{1A}$ = ask price of the call option with exercise price $E_{1C}$,
$C_{2B}$ = bid price of the call option with exercise price $E_{2C}$,
$P_{1B}$ = bid price of the put option with exercise price $E_{1P}$, where $E_{1C} = E_{1P}$,
$P_{2A}$ = ask price of the put option with exercise price $E_{2P}$, where $E_{2C} = E_{2P}$,
$t$ = time remaining to expiration of the futures-option, expressed as a fraction of a 365-day year, and
$r$ = riskless rate of return.[5]

[5]As a proxy for the risk free interest rate, daily U.S. Treasury Bill ask quotations are utilized in this study. The T-Bill quotations represent ask prices (and yields), at inception of the box spreads, for the contract maturing on the day before the expiration date of the futures-options. Ask yields are utilized as the benchmark riskless rate in this study since they represent the yield at which investors can purchase U.S. Treasury Bills. The quoted ask yields are subsequently converted into continuously compounded rates of return and inserted into eq. (2) as the riskless rate of return with which box-spread performance is determined.

According to eq. (2), the excess dollar return on a long box spread is computed as the difference between the present values of the inflows received and the outflows incurred at spread initiation and at option expiration. Initially, however, the cash flows of a long-spread position consist of the premia received from the two short futures-options, $P_{1B}$ and $C_{2B}$, net of the premia paid for the two long positions, $P_{2A}$ and $C_{1A}$. Since the long option positions are more valuable than the short positions, the net effect of the combination is a cash outflow at spread initiation. Upon expiration of the futures-option positions, the net proceeds from the purchase and sale of the respective positions equal the exercise-price spread, $(E_2 - E_1)$, adjusted for the bid–ask spread. Discounting this outcome to the point of spread construction at the continuously compounded, riskless rate of interest, and combining the result with the net costs incurred at the time of spread initiation produces the net excess dollar return on each box–spread position, $R_{BS}$.

A summary of the excess dollar returns produced by eq. (2) is provided in Table III, divided into subsamples based upon the time interval required to construct the composite position. According to Table III, the mean and median of each subsample are both negative, which indicates that the subsamples of box spreads are unprofitable since the dollar return on each corresponding Treasury Bill is positive. In addition, the dispersion of returns increases as the time interval widens, suggesting that tests of profitability may identify significant differences between box-spread and Treasury Bill dollar returns.

To test the null hypothesis of equal, excess dollar returns on the box-spread positions and the Treasury Bill contracts, a nonparametric

**TABLE III**

Summary of Excess Dollar Returns

| *Minutes* | *N* | *Mean* | *SD* | *Median* | *Min* | *Max* |
|---|---|---|---|---|---|---|
| 0 < interval ≤ 1 | 258 | 145.34 | 127.30 | 126.57 | 584.45 | 49.54 |
| 1 < interval ≤ 2 | 493 | 147.25 | 181.38 | 128.45 | 1094.62 | 327.87 |
| 2 < interval ≤ 3 | 782 | 149.83 | 209.98 | 131.64 | −1376.54 | 382.29 |
| 3 < interval ≤ 4 | 1166 | 152.95 | 220.74 | 135.04 | −1484.60 | 1319.37 |
| 4 < interval ≤ 5 | 1671 | 158.73 | 223.42 | 139.82 | −1966.48 | 1484.63 |

Minutes – the time interval required to construct the box spread positions
$N$ – the size of each subsample
Mean – average excess dollar returns for the specified samples of box-spread positions.
SD – the standard deviation of each subsample of box-spread excess dollar returns
Median – the median excess dollar return of each box-spread subsample
Min – the minimum excess dollar return for each subsample
Max – the maximum excess dollar return for each subsample

Wilcoxon signed-ranks procedure is performed.[6] A summary of the Wilcoxon test results is presented in Table IV.

The results of the Wilcoxon analysis indicate that the samples of box-spread and T-Bill excess dollar returns differ significantly at the 1% level. The Wilcoxon test results also confirm the findings presented in Table III, suggesting that profitability declines as the time interval required to establish the composite spread position is allowed to expand. Permitting greater periods of time to consummate the spread means that the fourth futures-option in a box spread could be effected up to five minutes after the initial option position is established. This process of noncontemporaneously constructing the composite position (characterized as *legging*) introduces significant risk into the composite transaction.[7] *Legging risk* in a box spread exists if the four futures-options are not simultaneously combined into the composite position, a situation which requires the box-spread arbitrageur to hold an unhedged position in one, two or three futures-options until the four option positions are established. The risks associated with legging are manifested if new information enters the market, thereby causing prices to change and generating revised intertemporal parity prices among the array of futures-options. For a spread arbitrageur who contemporaneously establishes fewer than the required four futures-option positions in a box spread, a change in relative prices would occlude the construction of a perfectly hedged composite position because the relative price parity that prevails when the initial position is established would no longer exist at the original prices.

**TABLE IV**

Wilcoxon Signed-Ranks Test Results

| *Minutes* | N | *Prob* > \|*Test Statistic* (S)\| |
|---|---|---|
| 0 < interval ≤ 1 | 258 | 0.0062[a] |
| 1 < interval ≤ 2 | 493 | 0.0031[a] |
| 2 < interval ≤ 3 | 782 | 0.0018[a] |
| 3 < interval ≤ 4 | 1166 | 0.0009[a] |
| 4 < interval ≤ 5 | 1671 | 0.0001[a] |

[a]Significant at the 1% level

[6] The results of a Shapiro–Wilk goodness of fit test indicate that each of the subsample box-spread distributions is non-normal at the 1% level of significance, while a Kolmogorov–Smirnov test for symmetry indicates that these subsamples are also asymmetrically distributed at the 1% level of significance.

[7] See Sofianos (1993).

Therefore, permitting wider time intervals to accommodate the construction of box spreads induces legging risk, and the presence of legging risk may significantly affect spread profitability, particularly if bid–ask spreads widen as new information enters the market. The Wilcoxon results provide evidence of increasing risk for the box spreads because, in the absence of new information affecting futures-options prices, the arbitrage process would ensure that excess returns would be unattainable on identically riskless instruments. The Wilcoxon statistics consequently indicate that, at the margin, the larger profits and losses are a function of increasingly nonsynchronous prices, rather than an indication of market inefficiency. In tests of market efficiency, therefore, the results of this study emphasize the importance of utilizing synchronous prices in empirical analyses, for if nonsynchronous prices are examined, the test design no longer compares riskless hedge positions.

## SUMMARY AND CONCLUSIONS

A fundamental requirement of market-efficiency studies is the accurate replication of actual market conditions. Galai (1977) indicates that the use of nonsynchronous price data to identify excess, riskless profits in tests of market efficiency may invalidate the results of empirical analyses. Therefore, the utilization of intra-day price data to construct nearly synchronous hedged positions represents one requirement of market-efficiency tests. Galai also suggests that tests of market efficiency must independently evaluate the market under consideration. Consequently, an analysis of pricing observations from multiple markets constitutes a joint-hypothesis test, and this process can bias test results toward a conclusion of market inefficiency. According to Phillips and Smith (1980), a third, and equally important, requirement of efficiency studies is the accurate adjustment of profits for transactions costs.

This study attempts to satisfy these requirements by employing the box-spread arbitrage model to evaluate the efficiency of the market for S&P 500 Index futures-options. Utilizing a modified Bhattacharya procedure to categorize undesignated transaction prices as bid or ask transactions, this study constructs cost-adjusted box spreads from bid and ask futures-options collectively quoted within designated time intervals ranging up to five minutes. The results of the nonparametric analysis indicate that, after adjusting for transactions costs, the box-spread positions generate significantly unprofitable returns.

The empirical results also reveal that the dispersion of returns accordingly increases as the time interval required to effect the composite position is permitted to expand. This finding implies that allowing expanded time intervals to construct the box spreads induces legging risk, while simultaneously facilitating an analysis of nonsynchronous prices in the spread positions. Therefore, rather than representing evidence of market inefficiency in S&P 500 Index futures-options and an opportunity for an astute trader to exploit futures-option mispricing, the excess profits and losses observed in the samples of box-spread returns are a function of increasingly nonsynchronous prices. In tests of market efficiency that examine riskless hedge positions, the results of this study amplify the importance of data synchronicity in empirical analyses.

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