THE PRICING OF STOCK INDEX FUTURES SPREADS AT CONTRACT EXPIRATION

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This paper conducts an empirical analysis of the mispricing of calendar spreads for stock index futures. Using recent data drawn from the Sydney Futures Exchange, a sharp increase in the magnitude of spread mispricing immediately prior to maturity of the near contract is documented. This pattern in mispricing is related to a sharp decline in open interest in the near contract and an increase in open interest in the deferred contract. Further, the direction of mispricing of the near and deferred contracts are more likely to move in opposite directions as the near contract approaches maturity. These findings are consistent with the hypothesis that traders seeking to roll-over their positions from near to deferred futures contracts close to maturity increase the magnitude of spread mispricing. © 2002 Wiley Periodicals, Inc. Jrl Fut Mark 22:451–469, 2002

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1. INTRODUCTION

The pricing efficiency of stock index futures markets[1] has generated a substantial volume of research by finance academics. The bulk of this literature has considered the pricing efficiency of futures contracts relative to the cash market. Evidence on U.S. stock index futures contract pricing efficiency, for example, may be found in Figlewski (1984), Chung (1991), and Dwyer, Locke, and Yu (1996); for UK markets in Yadav and Pope (1990, 1994); for Japanese markets in Brenner, Subrahmanyam, and Uno (1989) and Lim (1992); and for Australian markets in Brailsford and Hodgson (1997). In general, "empirical work has often contrasted with theoretical expectations with researchers finding evidence of substantial and sustained 'wave-like' mispricing between the spot and futures stock index markets. . ." (Brailsford & Hodgson, 1997, p. 22).

A second and less frequented area of this literature has considered the relative pricing efficiency of stock index futures contracts of different maturities (i.e., intramarket or calendar spreads). To our knowledge, the sole contribution specific to this area was provided by Billingsley and Chance (1988).[2] In this paper, the authors considered intramarket spreads using weekly data for the S&P 500 and New York Stock Exchange index futures contracts and found evidence of significant overpricing, which was not profitable once transaction costs were taken into account.

This lack of research into the behavior of calendar spreads represents a surprising oversight by the literature, as knowledge of the behavior of spreads is important.[3] For example, due to the cost advantages provided by futures markets (Fleming, Ostdiek, & Whaley, 1996), equity fund managers often create an exposure to the stock market by transacting in stock index futures rather than directly investing in the market itself (Koski & Pontiff, 1999). This exposure is maintained by continually rolling over the position from near to deferred contracts. Thus, a fund manager with a long position in stock index futures will simultaneously execute a sell trade in the near contract and buy trade in the deferred contract as

[1]The first exchange to introduce a stock index futures contract was the Kansas City Board of Trade, which began trading Value Line Composite Index futures in February 1982, followed by the Chicago Mercantile Exchange which began trading S&P 500 Index futures in April 1982. The Sydney Futures Exchange was the first futures exchange outside the United States to introduce a stock index futures contract in 1983.

[2]A subset of futures market research has examined spreads in commodities markets. For example, Barrett and Kolb (1995) and Girma and Paulson (1998) examine seasonality in agricultural and petroleum spreads, respectively.

[3]This is a view shared by Barrett and Kolb (1995, p. 69) who state "(a)lthough much, or even most, speculative activity in futures markets is conducted by trading spreads, the price behavior of spreads has received relatively little attention in the academic literature."

maturity approaches. For fund managers and hedgers who utilize such trading strategies, the mispricing of calendar spreads in stock index futures can represent a transaction cost as they may be forced to pay a premium to roll-over their position (over and above the cost of carry).

The behavior of futures exchanges would certainly appear to support the importance of calendar spreads as special facilities, regulations, and procedures have been developed for handling such transactions. For example, many screen traded markets—such as SYCOM on the Sydney Futures Exchange (SFE) and Globex_2 on the Chicago Mercantile Exchange—have built-in functions that allow traders to execute spreads by submitting a single order. Further, many futures exchanges implement special procedures and have special regulations governing the execution of spreads. For example, Sections 6.10 to 6.12 of the Trading Etiquette of the SFE and Section 542 of the Chicago Mercantile Exchange Rulebook govern the execution of spread transactions.

Thus, the pricing efficiency of calendar spreads is an important element of the quality of stock index futures markets. The aim of this article is to provide evidence as to the pricing efficiency of stock index futures spreads using recent data drawn from the SFE. A theoretical argument is developed in which spread mispricing is hypothesized to increase as the near contract draws closer to maturity and traders look to roll-over their positions from the near to the deferred contract. The empirical evidence generated by the data considered in this paper provides support for this hypothesis. The remainder of this paper is structured as follows. In Section 2, some theoretical discussion of the pricing relationship between contracts of different maturity is discussed and a number of hypotheses are developed. Section 3 sets out the data and method used to test the hypotheses, and Section 4 reports the results. The final section provides some concluding comments.

2. THEORETICAL FUTURES PRICES AND CALENDAR SPREADS

Assuming the following—all investors can borrow and lend at the risk-free rate; zero taxes and transaction costs; a known dividend yield; no restrictions on short sales; the full proceeds of short sales are made available to investors and ignoring marking to market—the theoretical price of a futures contract under the cost of carry model as derived by Cornell and French (1983) is:

$$f(0, T_1) = S(0)e^{(r(0,T_1) - d(0,T_1))T_1} \qquad (1)$$

where $f(0, T_1)$ is the current price of the futures contract expiring in T_1 years; $S(0)$ is the current stock index level, $r(0, T_1)$ is the annualized risk-free rate over the period $(0, T_1)$; $d(0, T_1)$ is the annualized dividend yield over the period $(0, T_1)$; and T_1 is the time to maturity of the contract. The theoretical price of a stock index futures contract with a longer time to maturity (T_2) is as follows:

$$f(0, T_2) = S(0)e^{(r(0,T_2) - d(0,T_2))T_2} \quad (2)$$

where the variables in equation (2) are analogous to those in equation (1), and $T_1 < T_2$.

Following Billingsley and Chance (1988), the theoretical spread between the near and deferred contract under the cost-of-carry model can be found by subtracting (1) from (2) and with some rearrangement yields:

$$f(0, T_2) - f(0, T_1) = S(0)[e^{(r(0,T_2) - d(0,T_2))T_2} - e^{(r(0,T_1) - d(0,T_1))T_1}] \quad (3)$$

2.1. Determinants of Spread Mispricing

Although the trading activity of arbitragers should promote the convergence of prices, frictions exist in the market that allow theoretical and observed futures prices to diverge. The scope for such mispricing is not a constant, however, as research has documented that the magnitude of index futures mispricing falls as contract maturity approaches (Brailsford & Hodgson, 1997; MacKinlay & Ramaswamy, 1988; Yadav & Pope, 1994). MacKinlay and Ramaswamy (1989) attribute this feature of index futures markets to the fact that at least three risks faced by arbitrage traders diminish as the time to maturity approaches. First, as the maturity date approaches, the number of stocks paying dividends in the underlying index falls and hence the costs of incorrectly predicting dividends also falls.[4] Second, unanticipated increases in costs associated with the daily marking to market of a futures arbitrage position are less likely to occur as maturity draws near, as are unanticipated changes in interest rates. Finally, since arbitrage typically involves the use of a subset (rather than all) of the stocks in the underlying index, errors in tracking the index are less likely to occur the closer to maturity. Taken together,

[4]In fact, given that corporations announce the magnitude of dividends and the ex-dividend date before the ex-dividend date, there will be a period of time immediately before the expiration of a contract when there is no uncertainty about dividends paid by underlying stocks.

these three factors imply that the closer a contract is to expiration, the smaller the mispricing necessary to induce arbitrage traders into the market to realign theoretical and actual futures prices. In the context of calendar spreads however, these three factors apply equally to near and deferred futures contracts. If there is a tendency for mispricing to be in the same direction, then the spread may still be appropriately priced.

In this article, a theory is put forward to explain calendar spread mispricing, which is based on the trading behavior of market participants. To understand the argument, recall that a number of different types of traders are likely to roll-over their position from the near to deferred contract as the former approaches maturity. These include speculators such as fund managers seeking to maintain exposure to the underlying market over an investment horizon exceeding the remaining life of the near contract; hedgers holding a position in the underlying asset across an expiration date and wishing to continue with their hedge are also likely to roll-over their positions; and arbitragers seeking to increase the profitability of their positions may also choose to roll-over their position on expiration of the near contract (Yadav & Pope, 1994).

These three groups of traders may attempt to roll-over their futures positions at any point in time prior to expiration of the near contract. An incentive exists, however, to attempt to roll-over as close to maturity of the near contract as is possible. Bessembinder and Seguin (1992) document a negative relationship between days to expiration and trading activity for the S&P 500 stock index futures contract traded on the CME. This increase in trading activity can have the effect of reducing bid ask spreads (McInish & Wood, 1992; Wang, Michaelski, Jordan, & Moriarty, 1994) and market impact costs (Aitken & Frino, 1996; Chan & Lakonishok, 1993). Thus, the volume of trade and open interest in the far contract increase as the expiration date of the near contract draws close, which lowers the transaction costs associated with rolling a position over into the next contract.

The rolling over of positions by market participants is argued to cause spreads to deviate from their theoretical levels. More specifically, as traders roll-over their positions they will execute opposite transactions in the near and deferred contracts. For example, traders long in futures seeking to roll-over their positions will short the near contract and go long in the deferred contract. This can have the effect of pushing down the price of the near contract, and pushing up the price of the deferred futures contract. A similar but opposite effect is expected if traders are seeking to roll-over short positions. Thus, while the direction of change in spread mispricing depends on whether traders on balance are looking to roll-over long or short positions, the magnitude of observed calendar spread mispricing will increase prior to contract maturity.[5]

The rolling over of futures positions by traders leads to two testable propositions about futures spread mispricing. The first such proposition is that the magnitude of calendar spread mispricing is likely to increase as the near term contract approaches maturity. As such, the following model may be estimated:

$$\Delta |M_t^s| = \alpha_0 + \sum_{i=1}^{n} \alpha_i D_i + \varepsilon_\tau \quad i = 1 \ldots 7 \tag{4}$$

where $|M_t^s|$ is the absolute daily average mispricing of the near and deferred futures index contract and D_i are weekly dummy variables designed to capture the pattern in each variable related to the time to expiration of the near contract (e.g., $D_1 = 1$ where $i = 1$ to 5 trading days prior to expiration of the near contract, else 0; $D_2 = 1$ where $i = 6$ to 10 else 0; etc.). Under the theory presented, a positive sign is expected for the dummy variable capturing the 5 trading days prior to expiration—i.e., $D_1 > 0$ and $D_1 > D_i$ where $i = 2$ to 7. The first difference of the mispricing variable is considered to limit problems associated with autocorrelation, which have been documented in prior research (Bessembinder & Seguin, 1992), and possible non-stationarity.[6] All t-statistics are also adjusted for autocorrelation and heteroskedasticity using the procedure outlined in Newey and West (1987).

Prior research suggests that futures spread mispricing may be related to price volatility and trading volume (see Brailsford & Hodgson, 1997). Further, the theory presented earlier implies that the increase in mispricing as the near contract approaches maturity is related to attempts by traders to roll-over their positions from the near to deferred contract. Thus, changes in the magnitude of mispricing of calendar spreads should be negatively related to changes in open interest in the near-term contract and positively related to changes in open

[5]If the number of traders seeking to roll-over a long position is exactly equal to the number of traders seeking to roll-over short positions, then where these traders arrive at the market simultaneously, they will offset each other with no impact on spread mispricing. If these traders do not arrive to the market simultaneously, however, then the magnitude of spreads may still deviate from their theoretical level.

[6]Stationarity of each time series was assessed using Augmented Dickey–Fuller tests. The results of this analysis suggested that while each series was nonstationary at conventional levels of significance, none of the first-differenced series exhibit a unit root.

interest in the deferred contract.[7] Hence in order to properly test the relationship between mispricing and time to maturity, it may be necessary to control for these three variables. Following Bessembinder and Seguin (1992), both open interest ($Interest_t$) and trading volume ($Volume_t$) are measured in contracts and price volatility may be measured as:

$$Volatility_t = \log(H_t) - \log(L_t) \tag{5}$$

where H_t is the highest price on day t and L_t is the lowest price. Wiggins (1992) provides evidence that volatility metrics based on extreme values (high/low) are more efficient than those based on closing prices. Taking into account each of these additional factors, equation (4) may be modified to:

$$\begin{aligned}\Delta|M_t^s| = {} & \alpha_0' + \beta_1 \Delta Interest_t^n + \beta_2 \Delta Interest_t^d + \beta_3 \Delta Volatility_t^n \\ & + \beta_5 \Delta Volume_t^n + \beta_6 \Delta Volume_t^d + \sum_{i=1}^{n} \alpha_i' D_i + \varepsilon_t \end{aligned} \tag{6}$$

where all variables are as defined above. In addition to the expected positive sign for D_1, the rolling over of positions by traders implies that $\beta_1 < 0$ and $\beta_2 > 0$.

The theorized behavior of traders also implies that the pressure on mispricing in the near and deferred contracts are likely to be in opposite directions prior to maturity. This observation leads to a second testable proposition—that the mispricing of the near and deferred futures contracts are more negatively related, the closer to expiration is the near contract. That is to say, as the near contract approaches maturity, the mispricing in the near and deferred contract are more likely to be in opposite directions. This may be tested using the following model:

$$\Delta M_t^n = \delta_0 + \delta_1 \Delta M_t^d + \sum_{i=1}^{7} \delta_i' \Delta M_t^d D_i + \varepsilon_t \tag{7}$$

where M_t^n is the mispricing of the near contract and M_t^d the deferred contract. The implication of the second testable proposition is that $\delta_1' < \delta_i'$ for $i = 2$ to 7, and $\delta_1' < 0$.

[7]We do not suggest that the decline in open interest in the near contract as it approaches maturity is solely caused by traders rolling over their positions. To the extent that the trades undertaken as a part of a roll-over strategy coincide with those trades initiated to close out a position in a maturing contract, the pressure on mispricing should be consistent.

3. INSTITUTIONAL SETTING AND DATA

The All Ordinaries Index (Allords) is a broad-based equity index comprising approximately 250 of the largest stocks traded on the Australian Stock Exchange (ASX) and represents around 90% of the total capitalization of the market. The stocks comprising the index are traded on the electronic trading system of the ASX called the Stock Exchange Automated Trading System (SEATS). The level of the Allords is calculated by the ASX and is reported to the market every 30 seconds.

Prior to 1999, trading of the Allords Share Price Index (SPI) futures contract on the SFE was conducted on a trading floor through continuous open outcry and was analogous to trading on the Chicago Mercantile Exchange, which has been analyzed in previous research (Chung, 1991; Dwyer et al., 1996; Figlewski, 1984). Trading in the SPI was conducted at a designated place on the floor of the SFE called a "pit." Each pit is occupied by a "Price Reporter," an exchange official. Price Reporters use microphones to communicate with Price Report System Operators located on a catwalk above the trading floor. Price Reporters communicate trade information to the Operator including trade prices and volumes as well as bid and ask quotes. The Operators then enter the trade information onto computer terminals, which automatically assign a time stamp to each trade. This data collection system is referred to as the Price Reporting System, and the data is sold online in real time to quote vendors. The format of the data sold to quote vendors conforms to Interexchange Technical Committee (ITC) standards, and is frequently referred to as ITC data. ITC data is comparable to U.S. data more commonly referred to as "time and sales" data. However, "time and sales" data reports the prices of price changing trades only. Hence the SFE's ITC data provides a unique opportunity to directly measure quoted bid ask spreads. Floor trading of the Share Price Index (SPI) futures commences at 9:50 a.m. and ends at 4:10 p.m. on the SFE. In contrast, the stocks from which the index is constructed are traded on the ASX from 10:00 a.m. to 4:00 p.m.[8] Unlike overseas exchanges and the ASX, trading on the SFE breaks for lunch between 12:30 p.m. and 2:00 p.m.

Since that time, a number of changes have taken place that have impacted on the trading of the Australian stock market share index futures contract. Most notably, in October 1999 the SFE joined the

[8]Stocks on the ASX do not open simultaneously. Rather, they are grouped according to their alphabetical ranking, and each group is opened randomly at different times between 9:59 a.m. and 10:09 a.m.

growing list of exchanges that have abandoned (or plan to abandon) floor trading in favor of electronic screen trading (such as the French futures market and the Hong Kong Futures Exchange). In the following month, the trading hours of the day session were extended to begin at 9:30 and conclude at 4:30. Another significant change occurred in 2000, with the ASX passing responsibility for the construction of Australian share market indices to Standard and Poor's. As a result, a number of new indices were introduced and the Allords was modified to a much broader market index encompassing approximately 500 stocks representing 98% of the Australian market capitalization. The SPI was subsequently changed to reference the S&P ASX 200 index (which captures 88% of the market) beginning with the June 2000 contract.

3.1. Data

This study uses end-of-day transactions data for the All Ordinaries Share Price Index (SPI) futures contract traded on the floor of the SFE. The sample period for this data was deliberately chosen so as to avoid any structural shifts such as the institutional changes discussed above.[9] The transactions data covers the period January 28, 1994 to September 30, 1997, which provides a structural break free data set of 15 SPI expirations for analysis.

The data describes the time (to the nearest second), price and volume underlying each trade, and the price associated with bids and offers. This data was provided by the SFE and captured by Price Reporters located on the floor of the exchange. End-of-day open-interest figures were also provided by the SFE. A minute-by-minute snapshot of the Allords and a daily dividend series was provided by the ASX. The dividend series contains the market capitalization and total actual dividends paid each day by stocks in the Allords. Finally, daily series for the overnight cash, 30-, 60-, 90-, 120-, and 180-day bank bill swap rates were provided by the Treasury Division of the Commonwealth Bank of Australia. The data is assembled for both near and deferred contracts 35 trading days prior to maturity for each contract. This is well within the first day in which each deferred contract commences trading continuously. While this limits the analysis, it avoids possible biases associated with conducting cross-sectional analysis across less than 15 contracts.

[9]As there are only four SPI contract expirations per year, any meaningful analysis of the impact of these changes on the relationship between CPI contract expiration and spread mispricing is precluded.

3.2. Variable Measurement

Equations (1) to (3) may be used to develop estimates of minute-by-minute theoretical prices for the near and deferred contracts as well as spreads. The computation of the theoretical futures price is based on realized dividends, which Harvey and Whaley (1992) argue reduces pricing errors introduced when future dividends are estimated. Thus, the dividend yield used in this study is the sum of dividends paid out by stocks over the remaining life of the contract divided by the market capitalization of stocks underlying the Allords at the beginning of each day. The relevant interest rate for the period representing the near and deferred contracts were interpolated from a yield curve based on the bank bill swap rates.[10]

The difference between the theoretical and actual index futures contract price, or level of mispricing, (M^j) may be calculated as:

$$M^j = P^j_a - P^j_{th} \tag{8}$$

where P^j_a is the actual futures price, P^j_{th} is the theoretical futures price, and $j = n$ (near contract) or d (deferred contract). Mispricing of the calendar spread (M^s) represents the difference between the actual futures spread and theoretical futures spread, and is equivalent to:

$$M^s = M^n - M^d \tag{9}$$

As all analysis in this paper is to be conducted at a daily frequency, which is the finest observation interval common to the data, the average daily mispricing for the near contract, deferred contract, and spread was calculated for each day and will be used in the empirical testing of each hypothesis.

4. RESULTS

Panel A of Table I provides some descriptive statistics for each of the mispricing series. The mean mispricing over the sample period is 4.4 points for the near contract, and 8.9 points for the deferred contract where each index point is valued at A$25. The average of the absolute value of mispricing for the near and deferred contracts is 10.3 and 14.9 points,

[10]An arithmetic interpolation procedure was used, involving the two interest rates which straddle the life of the contract (or spread) being priced.

TABLE I
Time-to-Expiration Patterns in Futures Contract Mispricing

	M_t^n	M_t^d	M_t^s	$\lvert M_t^n \rvert$	$\lvert M_t^d \rvert$	$\lvert M_t^s \rvert$
Panel A: Descriptive Statistics						
Mean	4.4	8.9	4.6	10.3	14.9	6.8
Median	4.9	9.8	5.1	15.0	13.7	6.0
st. dev.	11.7	15.5	6.8	7.1	10.1	4.7
N	433	433	433	433	433	433
Panel B: Time-to-Expiration Patterns						
α_0	2.2*	2.2*	−0.01	0.2	0.4	−0.01
	(2.6)	(2.4)	(0.0)	(0.2)	(0.5)	(0.1)
D_1	−2.9*	−3.2*	−0.26	−1.3	−0.5	1.3*
	(2.4)	(2.5)	(0.7)	(1.4)	(0.5)	(3.7)
D_2	−2.6*	−2.7*	−0.16	0.01	0.3	0.32
	(2.2)	(2.2)	(0.4)	(0.0)	(0.2)	(0.8)
D_3	−2.5*	−2.6*	0.02	−0.4	−0.8	−0.1
	(2.2)	(2.1)	(0.0)	(0.5)	(0.7)	(0.3)
D_5	−3.9*	−3.8*	0.07	−0.5	−1.4	0.1
	(3.1)	(2.5)	(0.1)	(0.6)	(1.2)	(0.1)
D_6	−2.0	−1.6	0.36	1.0	1.4	0.3
	(1.5)	(1.1)	(0.7)	(0.9)	(1.1)	(0.7)
D_7	−1.3	−1.4	−0.16	0.4	0.0	0.2
	(0.6)	(0.7)	(0.3)	(0.3)	(0.0)	(0.7)
adj R^2	0.03	0.03	0.01	0.01	0.02	0.05
F	1.9	1.8	0.4	1.0	1.4	3.7*

Notes. Panel A presents some summary statistics for the average daily mispricing of the near (M_t^n) and deferred (M_t^d) index futures contracts as well as the spread (M_t^s). Summary data for the absolute daily mispricing of the near ($\lvert M_t^n \rvert$) and deferred ($\lvert M_t^d \rvert$) index futures contracts as well as the spread ($\lvert M_t^s \rvert$) are also presented. Panel B presents the results of the regression equation $\Delta M_t = \alpha_0 + \Sigma\alpha_i D_i + \varepsilon_t$ where D_i is a time-to-expiration dummy variable ($\lvert M_t \rvert$ is the dependent variable in the final three columns).
Absolute values of t-statistics in parentheses. *Denotes significance at the 5% level.

respectively. These figures are all higher than similar estimates provided by Brailsford and Hodgson (1997) in which an average mispricing of 3 points and average absolute mispricing of 6.7 points is documented for the near SPI contract in 1993. The difference in results is attributable to the higher level of the Allords in more recent periods, which has the effect of making a given level of mispricing smaller in percentage terms. This implies that futures mispricing (in points) must be higher to be profitable and attract arbitragers into the market.

Panel B of Table I documents the relationship between each mispricing series and the time to expiration. The left half of Panel B reports the results of regressing the time to expiration dummy variables against the change in the daily average mispricing for the near, deferred and spread. Each of the estimated coefficients for lags 1–3, 5 is significant at the 5% level where the average mispricing of the near and deferred

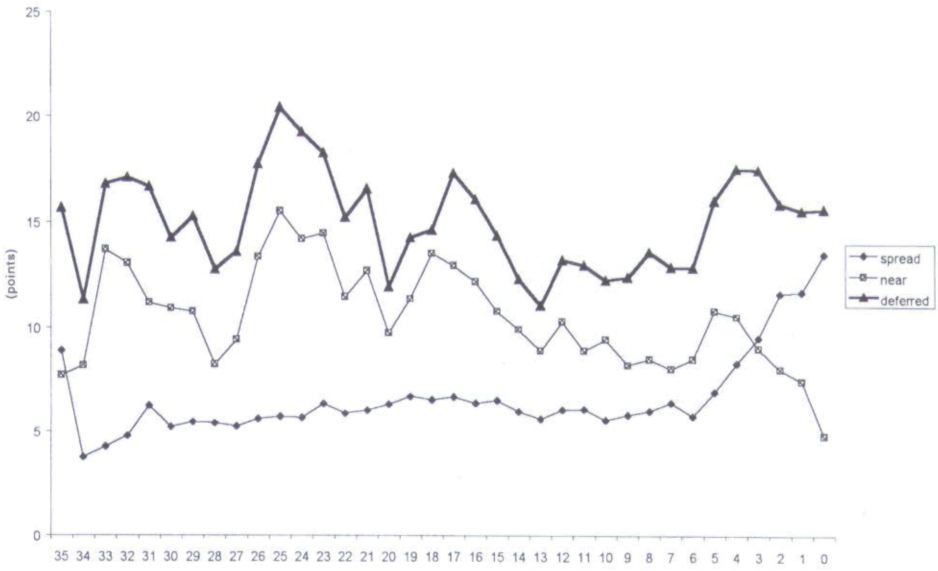

FIGURE 1
Time-to-expiration patterns in $|M_t|$ of near and deferred futures contracts.

contract is the dependent variable.[11] Where the average daily mispricing of the spread is the dependent variable, none of the estimated coefficients are significant. However, the F-statistics for each of these three estimated models are not significant at conventional levels, which is support for the joint hypothesis that all of the estimated coefficients are near zero. This is consistent with previous work examining the relationship between mispricing and time to expiration (e.g., Yadav & Pope, 1990).

Insights as to the nature of the relationship between time to maturity and the average daily absolute mispricing series may be gained by considering a plot of the data which is presented in Figure 1. While the mispricing of the near and deferred are closely related, they do not appear to track each other exactly. Further, while the mispricing of the spread is somewhat constant up until the last week prior to expiration, it increases notably in the last 5 days of trading. The right-hand side of Panel B in Table I empirically tests this relationship, and the estimated results suggest that there is little evidence of a time to maturity pattern in the average absolute value of mispricing for the near and deferred contracts in the 35 trading days prior to expiration of the near contract.

[11] To avoid the dummy variable trap, D_4 is excluded from n in which case the systematic pattern for each variable in the period of 11 to 15 days prior to maturity is impounded in the constant term.

This is in contrast to previous research that documents a strong and statistically significant time to expiration pattern in the absolute value of mispricing (e.g., Brailsford & Hodgson, 1997; MacKinlay & Ramaswamy, 1988; Yadav & Pope, 1990). The conflicting findings between the current study and prior research is attributable to differences in the research method. Prior research has typically regressed the level of absolute mispricing on a variable representing the number of days to maturity using a sample period extending well beyond 35 trading days prior to expiration.[12] The final column of Panel B in Table I reports the estimation results where the time to expiration dummy variables are regressed against the change in the average absolute level of spread mispricing. The coefficient on D_1 is positive and statistically significant at the 0.05 level, implying that calendar spread mispricing increases significantly in the 5 trading days prior to expiration. This is consistent with the first testable proposition which predicts that the absolute value of calendar spread mispricing will increase prior to maturity.

It is interesting to consider whether there are time to expiration patterns in open interest, trading volume, and price volatility for the near and deferred contracts. Further, the theory discussed in Section 2 also implies that bid ask spreads are likely to narrow as a contract approaches maturity, which provides the motivation for delaying rollover of contracts until immediately before the near contract expires. To provide some evidence on this issue, time weighted average bid ask spreads (see McInish & Wood, 1992) are also calculated. Figure 2 presents a plot of the mean of each of these variables against the time to maturity of the near contract. Panel A of Table II presents some summary statistics for each of these variables and the estimated results of equation (4) applied to each of these variables are presented in Panel B. The theory outlined in Section 2, suggests that the time to expiration patterns in spread mispricing are driven by roll-over activity from the near to deferred contract, and hence should be associated with a decline in open interest in the near contract and increase in open interest for the deferred contract. Consistent with this theory, Panel A of Figure 2 illustrates that open interest for the near contract is relatively stable, and then declines monotonically as the near contract approaches maturity. Further, the

[12]Following MacKinlay and Ramaswamy (1988), the daily average absolute mispricing was regressed against the number of days to maturity after stacking observations related to the near and deferred contract. The coefficient on the number of days to maturity was positive and statistically significant at the .001 level confirming that the difference in results reported in Table I and previous research is driven by the method used.

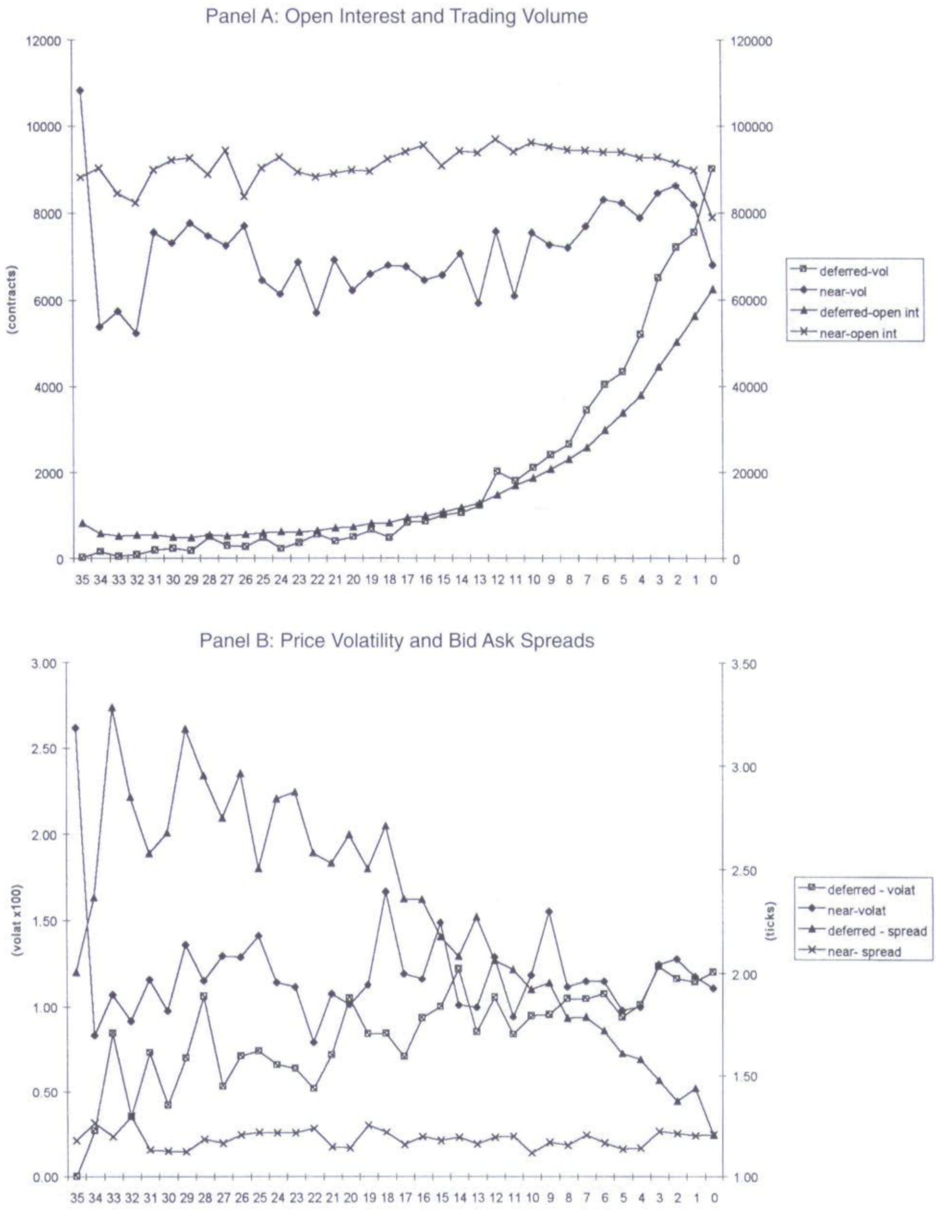

FIGURE 2
Time-to-expiration patterns in trading activity, price volatility, and bid-ask spreads.

figure documents a steady increase in the open interest in the deferred contract, as the near contract approaches maturity.

Panel B of Table II documents that the coefficient on the D_1 variable is negative and statistically significant for the change in daily open interest variable for the near contract, confirming that open interest in the near contract declines significantly in the 5 trading days prior to

TABLE II
Time-to-Expiration Patterns in Trading Activity, Price Volatility, and Bid-Ask Spreads

	Open Interest (contracts)		*Volume (contracts)*		*Volatility (×100)*		*Bid Ask Spreads (points)*	
	Near	*Deferred*	*Near*	*Deferred*	*Near*	*Deferred*	*Near*	*Deferred*
Panel A: Descriptive Statistics								
Mean	91,527	18,875	8,956	2,808	1.18	0.89	1.2	2.2
Median	90,350	11,717	8,546	1,383	0.99	0.8	1.1	2.1
std. dev.	20,252	17,167	3,220	3,411	0.89	0.64	0.1	0.7
N	433	433	433	433	433	433	433	433
Panel B: Time-to-Expiration Patterns								
α_0	809.0	754.7*	95.3	108.5	0.11	−0.01	0.01	−0.1
	(0.9)	(3.6)	(0.2)	(0.5)	(0.7)	(0.1)	(0.7)	(1.4)
D_1	−3802.3*	5219.5*	−438.6	932.3*	−0.09	0.05	0.01	0.02
	(3.1)	(18.2)	(0.7)	(3.2)	(0.4)	(0.4)	(0.1)	(0.1)
D_2	−1334.3	2337.7*	222.3	530.5	−0.14	0.02	−0.01	0.04
	(1.1)	(8.1)	(0.4)	(1.8)	(0.7)	(0.1)	(0.4)	(0.3)
D_3	−262.8	860.5*	37	167	−0.17	0.01	−0.03	0.04
	(0.2)	(3.0)	(0.1)	(0.5)	(0.8)	(0.0)	(1.2)	(0.4)
D_5	−673.8	−338.9	15.3	−89.9	−0.19	0.02	−0.02	0.02
	(0.5)	(1.1)	(0.0)	(0.2)	(0.8)	(0.1)	(0.7)	(0.1)
D_6	−421.6	−479.4	−291.6	−67.7	−0.01	0.09	−0.01	−0.03
	(0.3)	(1.5)	(0.4)	(0.2)	(0.0)	(0.5)	(0.0)	(0.2)
D_7	345.7	−695	660.8	−90.8	−0.12	0.03	−0.05	−0.01
	(0.2)	(1.5)	(0.6)	(0.1)	(0.3)	(0.1)	(1.3)	(0.0)
adj R^2	0.04	0.59	0.01	0.05	0.00	0.00	0.01	0.00
F	2.4*	102.1*	0.3	3.19*	0.2	0.2	0.7	0.0

Notes. Panel A presents some summary statistics for the daily trading activity, price volatility, and bid-ask spreads. Panel B present the results of the regression equation $\Delta V_t = \alpha_0 + \Sigma\alpha_i D_i + \varepsilon_t$ where V_t is open interest, volume, volatility or bid-ask spread and D_i is a time-to-expiration dummy variable.
Absolute values of t-statistics in parentheses. *Denotes significance at the 5% level.

maturity. The coefficients on D_1, D_2, D_3, and the constant term, are all positive and significant for the change in daily open interest variable for the deferred contract. Further, while Panel A of Table II provides some evidence of a time to expiration pattern in trading volume (D_1 is positive and significant for the deferred contract), there is little evidence of a pattern in price volatility. This is consistent with prior research by Grammatikos and Saunders (1986), which examined time to maturity patterns in trading volume and price variability for a wide variety of financial futures traded on the CME. Surprisingly, while bid ask spreads for the deferred contract appear to decline in Panel B of Figure 2, Table I suggests that the pattern is not statistically significant. In all, these results suggest that the time to expiration patterns in spread

TABLE III

Relationship Between Mispricing of Calendar Spreads and Open Interest

Variable	*Model 1* $\Delta\|M_t^s\|$	*Model 2* $\Delta\|M_t^s\|$
α_0	−0.1204 (0.5)	−0.1510 (0.6)
$\Delta\,Interest_t^n$	−0.0001 (2.3)*	−0.0001 (2.3)*
$\Delta\,Interest_t^d$	0.0001 (2.6)*	0.0002 (2.8)*
$\Delta\,Volatility$	—	10.9228 (1.2)
$\Delta\,Volume_t^n$	—	0.0001 (1.0)
$\Delta\,Volume_t^d$	—	−0.0001 (1.4)
D_1	0.3568 (0.7)	0.2296 (0.4)
D_2	−0.1106 (0.3)	−0.1559 (0.4)
D_3	−0.2718 (0.8)	−0.2757 (0.8)
D_5	0.0570 (0.1)	0.0768 (0.2)
D_6	0.3679 (0.9)	0.3896 (0.9)
D_7	0.3539 (0.6)	0.3647 (0.6)
adj R^2	0.08	0.09
F	3.9*	3.3*
N	412	412

Notes. The table presents the results of the regression equation:

$$\Delta|M_t^s| = \alpha_0' + \beta_1\,\Delta\,Interest_t^n + \beta_2\,\Delta\,Interest_t^d + \beta_3\,\Delta\,Volatility_t^n + \beta_5\,\Delta\,Volume_t^n + \beta_6\,\Delta\,Volume_t^d + \sum_{i=1}^{n}\alpha_i' D_i + \varepsilon_t$$

where M_t^s is the mispricing of the calendar spread, $Interest^{n(d)}$ is open interest in the near (deferred) contact, $Volume^{n(d)}$ is trading volume in the near (deferred) contract and D_i is a time-to-expiration dummy variable. Absolute values of t-statistics in parentheses. *Denotes significance at the 5% level.

mispricing documented in Table I may be influenced by factors related to open interest and trading volume, but not price volatility or bid ask spreads.

Table III provides the estimated results from a regression of the change in the magnitude of spread mispricing on the time to expiration dummy variables after controlling for changes in open interest (Model 1), as well as changes in volume and price volatility (Model 2). Three important results emerge from the table. First, the coefficient on the change in open interest for the near contract ($\Delta Interest_t^n$) is negative and significant, the coefficient on the change in open interest for the deferred contract ($\Delta Interest_t^d$) is positive and significant, and the F-statistics for both models are all significant at the 0.05 level. Second, the results for Model 1 imply that after controlling for changes in open interest, the time-to-expiration dummy variables are no longer significant, indicating that the time to expiration patterns in mispricing are explained by the changes in open interest. Finally, the results for Model 2 indicate that trading volume and price volatility provide little incremental explanatory power and are not significantly related to spread mispricing. These results imply that the increase in the magnitude of

TABLE IV

Relationship Between Mispricing of Near and Deferred Contracts

	Model 1 ΔM_t^n	*Model 2* ΔM_t^n
α_0	−0.004 (0.03)	—
ΔM_t^d	0.892 (61.7)*	0.972 (40.3)*
$\Delta M_t^d D_1$	—	−0.400 (8.8)*
$\Delta M_t^d D_2$	—	−0.132 (2.7)*
$\Delta M_t^d D_3$	—	−0.061 (1.4)
$\Delta M_t^d D_5$	—	−0.027 (0.6)
$\Delta M_t^d D_6$	—	−0.117 (2.2)*
$\Delta M_t^d D_7$	—	0.078 (0.9)
adj R^2	0.9	0.91
F	3809.4*	585.4*
N	412	412

Notes. This table presents the results of the regression equation:

$$\Delta M_t^n = \delta_0 + \delta_1 \Delta M_t^d + \sum_{i=1}^{7} \delta_i' \Delta M_t^d D_i + \varepsilon_t$$

where $M_t^{n(d)}$ is the mispricing of the near (deferred) contract and D_i is a time to expiry dummy variable. Absolute values of t-statistics in parentheses. *Denotes significance at the 5% level.

spread mispricing as the near contract approaches maturity is related to the fall in open interest of the near contract and increase in open interest of the deferred contract.

The first model presented in Table IV, provides the results of regressing the change in mispricing in the near contract (ΔM_t^n) on the change in mispricing of the deferred contract (ΔM_t^d). The second model extends the first to also include a number of interactive dummy variables designed to capture the change in this relationship as the near contract approaches maturity. Model 1 indicates that there is a very strong positive relationship in changes in near contract and deferred contract mispricing and the equivalent coefficient reported in Model 2 indicates that the relationship is near unity. Hence an increase in mispricing of the near contract is associated with a similar increase in mispricing of the deferred contract. Further, and most importantly, the coefficients on the interactive dummy variables $\Delta M_t^d D_1$ and $\Delta M_t^d D_2$, are both negative and significant at the 0.05 level. This implies that the positive relationship between mispricing of near and deferred contracts falls significantly in the 10 days prior to maturity, which is evidence in favor of the second testable proposition. These results also explain why the increase in the absolute value of mispricing observed in spreads prior to maturity is not also documented in the near and deferred contracts separately. These results imply that while mispricing remains roughly the same in *magnitude* for the near and deferred contracts as the near contract approaches expiration, they are more likely to be in opposite *directions*, thereby resulting in an increase in mispricing of the spread.

5. CONCLUSION

This article documents a sharp increase in the magnitude of spread mispricing immediately prior to maturity of the near contract. This mispricing is related to a sharp decline in open interest in the near contract and an increase in open interest in the deferred contract, after controlling for other possible determinants of spread mispricing. Further, while there is little evidence of an increase in the magnitude of mispricing of the near and deferred contracts as the near contract approaches maturity, the direction of mispricing of the near and deferred contracts are more likely to be in opposite directions. These findings are consistent with the hypothesis that traders seeking to roll-over their positions from near to deferred futures contracts increase the magnitude of spread mispricing prior to maturity.

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