Bid–Ask Spreads in Financial Futures

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INTRODUCTION

Transactions costs are usually ignored in asset pricing theories but are an important consideration in investors' investment decisions. One significant cost is the bid–ask spread, which is compensation to dealers for providing liquidity services in a continuously traded market. Microstructure researchers have examined empirically the nature of the bid–ask spread in the equity markets. Knowledge of futures spreads is limited, however, presumably because of a lack of information on bid–ask quotes. All bids and offers in futures markets must be announced by open outcry but are not binding on dealers. This, plus the futures microstructure itself, make it difficult for a pit recorder to account for every quoted bid–ask price. Moreover, the (unobserved) *effective* spread reflects actual trade sizes, whereas the *quoted* spread is for trades of normal size.

Transactions costs related to futures spreads is an important issue for several reasons. The low cost of trading is often cited as one rationale for the existence of futures markets. Transactions costs affect market participants' ability to trade quickly at an acceptable cost and limit the extent to which arbitrage provides a close link between cash and futures prices. Regulators also consider how their policy decisions impact liquidity and spreads, e.g., the controversy over eliminating dual trading.[1] In addition, insights into transactions costs associated with equity bid–ask spreads

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[1]Dual trading refers to futures exchange members who can act as brokers in executing customer orders and who can trade for their own account. Critics of this practice argue that a potential conflict of interest is created. Proponents argue that liquidity and market efficiency are increased and, consequently, less volatile prices and lower bid–ask spreads occur. See Smith and Whaley (1990) for a discussion of the issues and costs.

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cannot be directly applied to futures markets, because the two markets' financial instruments and microstructure differ in important ways.[2]

Although quoted bid–ask prices are not available for futures, an effective bid–ask spread can be estimated from a time series of price changes. Given that the first-order serial covariance of price changes is due only to the covariance induced by the spread, Roll (1984) develops a spread estimator that has been applied to equity markets.[3] Futures markets, on the other hand, appear to be more appropriate for applying his estimator because such markets more closely satisfy its assumptions. In this study, bid–ask spreads are estimated by using intraday price changes of two currency and interest rate contracts and a modification of Roll's spread estimator. The magnitude and behavior of the four contracts' effective spreads are analyzed by month-to-expiration to determine whether spreads vary over the life of a contract and whether they differ across related contracts. Unlike equities, futures have an expiration date as well as characteristics that change systematically as expiration approaches. Both trading volume and open interest, for instance, tend to rise until near expiration when both begin to decline toward zero. This is important because studies of the association between equity spreads and individual security characteristics find the spread to be inversely related to trading activity.

ROLL'S SPREAD ESTIMATOR

Early research shows that the bid–ask spread influences transaction price behavior, e.g., Niederhoffer and Osborne (1966). With randomly arriving sell and buy orders, a spread induces negative serial correlation in price changes as trades "bounce" between the bid and ask prices. Roll (1984) demonstrates that the first-order serial covariance of price changes may be used to estimate an effective bid–ask spread. If the price change on transaction t, ΔP_t, is given by

$$\Delta P_t = sD_t + e_t, \tag{1}$$

where

s = the dollar bid–ask spread;

$$D_t = \begin{cases} -1 & \text{if transaction } t \text{ is at the bid and transaction } t-1 \text{ is at the ask},\\ 0 & \text{if transactions } t \text{ and } t-1 \text{ are both at the bid (ask)},\\ +1 & \text{if transaction } t \text{ is at the ask and transaction } t-1 \text{ is at the bid;} \end{cases}$$

e_t = an i.i.d. random innovation in the underlying intrinsic value of the security with $E(e_t) = 0$ and $\mathrm{var}(e_t) = \sigma^2$.

D_t serves as an order flow index that is assumed to be independent of and serially uncorrelated with e_t. Stated differently, the conditions explicitly assumed by Roll are (1) markets are informationally efficient; (2) the underlying distribution of price changes is stationary; and (3) buy and sell orders arrive with equal probability, i.e., they are serially independent. In addition, this estimator implicitly assumes that the dealer determines a spread that brackets his/her estimate of the true price, but does not manage the placement of the spread. From eq. (1), the serial covariance of

[2] See Kamara (1988) for a discussion why price disparities between substitute goods traded in different markets are due to market microstructure differences.

[3] For example, see Amihud and Mendelson (1987), Haller and Stoll (1989), and Hasbrouck and Ho (1987).

successive price changes is

$$\operatorname{cov}(\Delta P_t, \Delta P_{t-1}) = \operatorname{cov}(sD_t, e_{t-1}) + \operatorname{cov}(sD_{t-1}, e_t) + \operatorname{cov}(e_t, e_{t-1}) + s^2 \operatorname{cov}(D_t, D_{t-1})$$

The first three terms are zero in an efficient market. Roll shows that by counting the number of possible price paths between the bid and ask over two consecutive trades, $\operatorname{cov}(D_t, D_{t-1}) = -1/4$, so $\operatorname{cov}(\Delta P_t, \Delta P_{t-1}) = -1/4\, s^2$. The effective spread then is

$$s = 2\sqrt{-\operatorname{cov}(\Delta P_t, \Delta P_{t-1})} \qquad (2)$$

Under Roll's assumptions, this measure is robust to random innovations in a security's value and to any arbitrary time interval over which price changes are observed. That is, the measure remains valid even if daily or weekly, rather than successive, price changes are used. This is because the proportion of possible price paths leading to any given price change over the total time period should be invariant to the sampling interval.

Roll uses this method to estimate the *percentage* spreads based on one- and five-day (weekly) returns for stocks over 1963–1982.[4] His results, however, are problematic: the average effective spread for daily data is unstable, and a high proportion of the daily and weekly spread estimates are negative, i.e., 51.4% and 34.8% of the daily and weekly spreads are negative. The weekly spreads also tend to be six times larger than the daily spreads. Roll attributes these unexpected results to either a lack of informational efficiency or time-dependent expected returns that induce positive autocorrelation (negative spreads) in shorter versus longer term returns.[5]

To explain these results, researchers have shown that if Roll's assumptions are violated his serial covariance estimator provides a downward-biased spread estimate. For example, Choi, Salandro, and Shastri (1988) introduce an unequal probability assumption regarding order arrivals, which is appropriate if order arrivals occur in runs. Glosten (1987) shows that the Roll estimator fails to capture an asymmetric information component in the spread because this component does not induce a "bounce" between bid and ask prices. Stoll (1989) develops a more general bid–ask spread model that considers three dealer costs that a quoted spread must cover: asymmetric information, inventory holding, and order processing. In this theoretical model, the Roll estimator provides a lower bound for the spread because it does not account for inventory and information costs of the management of the spread's placement. Stoll's empirical evidence on NASDAQ stocks also confirms that the Roll measure is downward biased for equity spreads, because each theoretical component contributes significantly to the spread.

[4]Roll, as well as other studies of equity bid–ask spreads, apply this estimator using serial covariances of returns rather than price changes and, thereby, measure percentage spreads. Percentage spreads in futures are difficult to interpret at best. Dividing a spread by futures price connotes little meaning because the price does not reflect an investment. In this study the first difference in price changes or dollar spread in terms of ticks (or, equivalently, in dollars since each tick has a fixed dollar value) is used.

[5]That is, underlying value changes exhibit positive serial correlation [see Amihud and Mendelson (1987) and Hasbrouck and Ho (1987)]. At least three factors excluded by Roll's assumptions may induce positive serial correlation in price changes: (1) sequential information arrival or, equivalently, sequential revisions in expectations; (2) execution of limit orders; and (3) lagged response to new information. The latter two factors are not likely to influence price behavior over daily or weekly intervals, but could be more important in transactions prices such as in this study. See Schwartz (1988) for further discussion.

Arguments that a bias is introduced into Roll's spread estimator by ignoring asymmetric information and inventory management are less compelling with regard to futures. Asymmetric information due to substantial private information is less likely to occur with a futures contract whose price is governed by macroeconomic events [Miller (1990)]. An individual stock price, in contrast, is largely determined by privately produced, firm-specific information. Inventory costs in futures trading also should be lower, and perhaps negligible, because most floor traders hold positions for only a short time. Silber's (1984) study of a representative scalper finds that the average holding period for a position is less than two minutes. Scalpers also can easily hedge with an offsetting position in a related contract on the same exchange. An equity dealer has to hedge with instruments in another market such as options and may even be prohibited from doing so [see Ho and Macris (1984)]. All this provides additional motivation for using Roll's estimator to measure futures' spreads: they primarily reflect order processing costs and thus approximate Roll's ideal conditions more closely.

Even though biases due to violations of Roll's assumption on the nature of market-maker costs are documented for equity and option markets, they do not explain why serial covariances are frequently positive. Retaining Roll's assumptions, Harris (1990) demonstrates that a large percentage of positive serial covariances can arise from statistical biases and noise. The biases are due to small sample properties of the serial covariance estimator itself and to Jensen's inequality. This study's application of Roll's estimator is designed to mitigate some of these problems.

Harris derives the small sample properties of the usual serial covariance estimator, $s\text{cov} = 1/T\, \Sigma \Delta P_t \Delta P_{t-1} - \overline{\Delta P}^2$ where $\overline{\Delta P}$ is the sample mean of a sequence of price changes, as

$$E(s\text{cov}) \approx -\frac{s^2}{4} - \frac{\sigma^2}{T} \tag{3}$$

and

$$\text{var}(s\text{cov}) \approx \frac{5/16\, s^4 + s^2\sigma^2 + \sigma^4}{T} \tag{4}$$

where T is the total number of observations and higher-order terms in $1/T$ are ignored. Equation (3) says the serial covariance estimator has a downward bias equal to σ^2/T, which results from $\overline{\Delta P}$ being an estimator of the true mean price change. Moreover, as the time interval over which ΔP_t is measured increases, σ^2 will usually increase while the number of observations decreases. Thus, this bias is especially critical for small samples of long return intervals.[6] In this intraday study, this bias should be minimized because price changes are measured over very short time intervals.

An offsetting bias is introduced by Jensen's inequality when the serial covariance estimates is transformed by the square root. The desired spread measure is $-1/4\sqrt{\text{cov}(\Delta P_t, \Delta P_{t-1})}$, but the true serial covariance is unknown. In the usual

[6]Thus, if the first bias dominates, weekly spreads will tend to be larger than daily spreads. While this is obviously what Harris has in mind, he estimates that this bias explains only about 30% of the difference between Roll's daily and weekly spread estimates. Stoll (1989) provides an alternative microstructure explanation for this phenomenon. Dealers may set prices designed to elicit reversing trades and are likely to be more successful in doing so over longer rather than shorter periods. Serial covariances, thus, would be more negative the longer the returns period.

application of the Roll estimator, the sample period is partitioned to obtain several estimates of $s$cov. Because the square root is applied to each subsample $s$cov before averaging them to get the effective spread, an estimate of $E\sqrt{-s\text{cov}}$ rather than $\sqrt{E(-s\text{cov})}$ is used. Because the square root is a concave function, spreads are downward biased. This bias becomes more important when price changes are measured over long time periods, because the noise in the serial covariance estimator is greater [see eq. (4)].[7] To alleviate this problem, short-period price changes and a single $s$cov over a long period are used rather than the mean of noisier $s$covs over various subperiods.

Finally, Harris reasons that a large proportion of negative spread estimates could be the result of noise. He analyzes this by examining the ratio of eqs. (3) and (4) as a measure of potential error, which increases linearly in absolute value with s/σ. Thus, sufficient noise will cause a significant number of negative spreads. Noise also should become worse, *ceteris paribus,* as the ΔP sampling interval increases, because σ increases with intervalling while s is constant. To address this problem this study uses a very short time interval to measure price changes, which also increases the number of observations for a given time period.

EMPIRICAL DESIGN

Data Description

Four financial futures traded on the Chicago Mercantile Exchange's (CME) International Monetary Market are analyzed: the Deutsche mark (DM), Swiss franc (SF), 90-day Treasury bill (TB), and 90-day Eurodollar loan deposit (ED). Table I, panel A indicates that the two currency contract specifications are nearly identical as well as the two interest rate contracts. This facilitates intermarket comparisons and the measurement of their effective spreads in terms of ticks or dollars (the minimum tick and its value are identical for the two types of contracts). The currency futures are quoted in 1/100 of a U.S. cent worth \$12.50 per contract, while interest rate futures are stated in basis points worth \$25 per basis point. All contracts have a single delivery day per contract month and similar delivery procedures. The currencies' last trading days are the same and close together for the interest rate contracts. Panel B indicates that the currency trading volumes are comparable, with the SF being somewhat lower after 1983. The two interest rate contracts provide a contrast. TB volume steadily declines over the test period, while the ED volume increases dramatically.

Transaction price data are taken from the CME's *Time and Sales* tapes, which contain every price change time stamped to the nearest minute. The four CME contracts' nearby and next nearby delivery months are studied over the December 1982 to December 1986 time period. This provides data for those six months closest to each contract's 16 expiration dates (four delivery months per year). The nearby deliver month is used to measure spreads in the "front months," or the three months closest to expiration. The next nearby delivery month is used for the "back months," or the next three months from expiration. Price changes are calculated for each 30-minute time bracket for a given trading day, using the last price in each bracket. This gives a total of 12 observations per trading day. Time-bracketed rather than

[7]Regarding the second source of bias, Roll recognizes the Jensen inequality problem but dismisses it as being empirically unimportant. Harris, on the other hand, finds it to be of significance.

Table I
CONTRACT SPECIFICATIONS AND TRADING VOLUMES FOR THE FOREIGN CURRENCY AND INTEREST RATE FUTURES

A. Contract Specifications[a]

Unit	Contract Size	Price	Minimum Tick	Tick Value	Normal Trading Hours (CST)
Deutsche mark	125,000 marks	Dollars/mark	\$0.0001	\$12.50	7:30 AM–1:20 PM[b]
Swiss franc	125,000 francs	Dollars/franc	\$0.0001	\$12.50	7:30 AM–1:16 PM[b]
Treasury bill	\$1 million, 90-day T-bills	IMM index[c]	0.01%	\$25.00	7:20 AM–2:00 PM[d]
Eurodollar	\$1 million, 90-day ED loan deposits[e]	IMM index[c]	0.01%	\$25.00	7:20 AM–2:00 PM[d]

B. Annual Trading Volume (in thousands)

Unit	1983	1984	1985	1986
Deutsche mark	2424	5508	6449	6582
Swiss franc	3766	4130	4758	4998
Treasury bill	3790	3293	2413	1815
Eurodollar	891	4193	8901	10,825

[a]The trading month cycle for all four contracts is March–June–September–December. In addition, the last trading day for currencies is identical, i.e., the second business day before the third Wednesday of the contract month. The interest rate futures' last trading day may differ, however. For the ED contract, it is the second London bank business day immediately preceding the third Wednesday of the contract month. For the TB contract, it is the business day immediately preceding the first delivery day. The last trading day is the second business day immediately preceding the third Wednesday of the contract month until June 1983. Thereafter, the business day immediately preceding the first delivery date is the first day of the contract month on which a 13-week Treasury bill is issued *and* a one-year Treasury bill has 13 weeks remaining in maturity.

[b]For DMs, trading begins at 7:34 AM, 7:30 AM, and 7:20 AM, respectively, in 1983, 1984–1985, and 1986. For SFs, trading opens at 7:30 AM and 7:20 AM, respectively, for 1983–1985 and 1986.

[c]The IMM index is the difference between 100.00 and the actual yield. In addition, TB and ED rates are quoted on a discount and add-on yield basis, respectively.

[d]TB trading opens at 8:00 AM in 1983. Until October 15, 1985, ED and TB trading starts at 7:30 AM; thereafter at 7:20 AM.

[e]The delivery procedure for the ED contract calls for cash settlement, whereas the other three contracts require physical delivery.

individual price changes are used because the Roll estimator depends upon zero price changes, but the CME data exclude transactions with a zero price change.[8] Overnight, weekend and holiday price changes (close-to-open) are excluded because evidence indicates that a different price formation process exists during nontrading hours.

[8]See Smith and Whaley (1990) for an alternative way to use the data.

Methodology

Unlike common stock, a futures contract has a specific expiration and systematically changing characteristics as expiration nears. For instance, open interest and trading volume tend to rise over a contract's life before peaking about two months before expiration. Samuelson (1965) also shows that futures price volatility should change systematically as expiration nears. That is, a nearby delivery month's prices should react more intensely to information affecting the spot market than prices on delivery months farther out. Anderson (1985) and Milonas (1986) find supporting evidence for this phenomenon in a number of futures, including financial futures. For these reasons, the data of this study are divided into six month-to-expiration categories, or month −1 to −6. Because the four futures contracts expire around mid-month, the beginning and end of a "month" is approximately mid-calendar month.

A point estimate of serial covariance for each month-to-expiration category, j, is then calculated as

$$scov_j = \frac{1}{T_j}\sum_{t=1}^{T_j} \Delta P_{j,t}\Delta P_{j,t-1} - \overline{\Delta P}_j^2 \qquad j = -6, -5, \ldots, -1 \tag{5}$$

where t now indexes each 30-minute interval over which a price change is measured and T_j is the number of half-hourly price changes in category j for a particular futures contract. In applying eq. (5), a pooled-data method is used. To illustrate, the first sample is all half-hourly price changes that occur during the last month before expiration, $j = -1$, for the DM's 16 delivery months during 1983–1986. Using eq. (2), a spread estimate for DM month −1 is calculated from this sample. This procedure is applied to the DM's other five month-to-expiration categories and then replicated for the other three futures contracts. This approach is designed to minimize the Jensen inequality bias and noise problems discussed earlier and is referred to as the "modified estimator." In contrast, Roll and others average a *subsample* of *s*cov estimates to compute an effective spread. For comparison, each delivery month contained in category j is used to calculate 16 individual *s*cov estimates, which are then averaged to compute an effective spread for month-to-expiration j. This procedure is referred to as the "Roll estimator."

Because the effective spread's statistical properties are due to the serial covariance estimator, tests of statistical significance are performed on the *s*cov estimator. First, Wilk's test is used to determine if an individual *s*cov equals zero. The test statistic is given by $W_j = -[2(T_j - 1)^2/2(T_j - 1) + 3]/(1 - r_j)^2$, where r_j is the correlation coefficient of ΔP_t and ΔP_{t-1} for month j and W_j is approximately χ^2 under the null hypothesis of zero covariance [see Morrison (1976), p. 258]. Because Wilks' statistic is a likelihood ratio test that depends on normally distributed price changes, a nonparametric correlation measure (Kendall's tau) is used to provide additional evidence on whether the first-order serial covariance is negative. To test for the equality of two spreads (*s*covs), a test for differences in second moments and co-movements designed by Box (1949) is performed. For a comparison of two covariances $scov_j$ and $scov_k$, the Box-M statistic is

$$M_{jk} = \frac{5}{18}\left(\frac{1}{T_j} + \frac{1}{T_k} + \frac{1}{T_j + T_k}\right)[(T_j + T_k)\ln|\overline{scov}| - T_j \ln|scov_j| - T_k \ln|scov_k|]$$

where subscripts index the two sample serial covariances of interest; T_j and T_k are the sample sizes used in computing $scov_j$ and $scov_k$, and $\overline{scov} = (T_j scov_j + T_k scov_k)/(T_j + T_k)$. M_{jk} is distributed approximately $\chi^2(3)$ under the null hypothesis that $scov_j = scov_k$.[9]

ESTIMATED SPREADS FOR FINANCIAL FUTURES

Table II contains the four futures' effective bid–ask spreads using the modified and Roll estimators. The two estimators' spreads are typically positive. For the modified estimator, the exceptions are the spreads in SF months −2 and −3 and ED months −4 and −6. Two spreads are negative with the Roll estimator. These results contrast with evidence from the equity markets, where effective spreads are negative 20–40% of the time [see Roll (1984) and Harris (1990)]. Therefore, more frequent price sampling (shorter time intervals) appears to improve spread estimation by reducing the proportion of positive *scov*s or negative spreads.

Spread behavior by month to expiration tends to display a "dipper effect" that is inverse to trading activity. Spreads in the three months closest to expiration are generally smaller than those in the three back months, with ED months −4 through −6 being the exceptions. The lowest spreads occur in months −2 and −3 in which volume and open interest are at their highest level. Month −1 spreads are somewhat larger because volume and open interest are approaching zero as expiration nears. In the back months, spreads become wider as time to expiration increases and trading activity wanes.

Magnitudes of the modified estimator's front-month spreads are consistent also with the stylized fact that actively traded contracts' spreads are about one tick, or \$12.50 and \$25 for currency and interest rate futures, respectively. Spreads in the DM and SF back months, however, are more on the order of three to five ticks, or \$37.50 to \$62.50. Interest rate spreads tend to be smaller than currency spreads, with all TB and the ED front-month spreads being about one tick.

Statistical tests performed on the serial covariances underlying the spread estimates indicate that noise is still present. Ten of the modified estimator's *scov*s do not differ from zero at a 5% level of significance using Wilks test. This includes the (positive) *scov*s for the four negative spreads. Kendall's tau indicates significant negative serial correlation at the 5% level in all but five cases, and three are the ED back months. Interestingly for all four futures, month −3 spreads are indistinguishable from zero under Wilks test but different from zero under Kendall's test. It is plausible that these spreads are between zero and one tick because month −3 is the most active trading period. The ED back months, however, are the most troublesome because their spreads are not different from zero under either test, yet should be the largest due to relatively little trading activity. For the Roll estimator, a standard t-test yields results similar to those obtained with the modified estimator.

Thus, this modified approach does not appear to eliminate the noise in the usual Roll serial covariance spread estimator. Nevertheless, the use of a single *scov* estimate derived from a long price series avoids the Jensen inequality bias. That is, where both estimators' spreads are significantly different from zero, the modified estimator spreads are always larger. For the interest rate contracts, the difference is

[9]See Box (1949) and Morrison (1976) for further discussion of this test statistic. Cho and Taylor (1987) contains an application of Box-M to equity markets.

Table II
EFFECTIVE BID–ASK SPREADS USING THE MODIFIED AND ROLL ESTIMATOR AND MEASURED IN TICKS BY MONTH-TO-EXPIRATION, 1983–1986 (ALL HALF-HOURLY TIME PERIODS)

Futures Contract	Month-to-Expiration	Effective Spreads[a] Modified Estimator	Roll Estimator	Kendall's Tau[b]	No. of Observations
Deutsche mark	−1	2.348†	0.862	−0.043*	3370
	−2	1.547	1.156*	−0.040*	3872
	−3	0.939	0.355	−0.046*	3773
	−4	3.083*	1.717†	−0.046*	3492
	−5	3.426*	2.767*	−0.060*	3411
	−6	3.343*	1.661†	−0.062*	2165
Swiss franc	−1	2.344	0.808	−0.023‡	3372
	−2	−1.272	−0.457	−0.005	3872
	−3	−1.619	0.028	−0.029*	3773
	−4	2.923†	1.219	−0.035*	3486
	−5	4.021*	2.603*	−0.051*	3406
	−6	5.544*	4.558*	−0.074*	2195
Treasury bill	−1	0.967*	0.802*	−0.059*	2908
	−2	0.954*	0.636*	−0.066*	3530
	−3	0.578	0.406‡	−0.037*	3565
	−4	0.881*	0.699*	−0.063*	3507
	−5	1.028*	0.867*	−0.061*	3128
	−6	1.077*	0.853*	−0.068*	2678
Eurodollar	−1	1.169*	1.030*	−0.095*	3056
	−2	0.853†	0.635*	−0.040*	3923
	−3	0.799‡	0.574*	−0.033*	3899
	−4	−0.345	0.150	−0.009	3625
	−5	0.414	0.230	−0.008	3557
	−6	−0.653	−0.084	−0.001	3228

[a]The statistical tests of significance are applied to the (unreported) first-order serial covariance estimates used to determine the effective spreads. A Wilks test is used with the modified estimator's *scovs*, and a standard *t*-test is used with the Roll estimator's *scovs*. The level of significance for a one-tailed test that *scov* is statistically different from zero is designated as follows: *1% level, †5% level, and ‡10% level.

[b]Kendall's tau, a nonparametric correlation measure, is calculated as additional evidence that the first-order serial covariance is negative and significantly different from zero. These statistics only apply to the modified estimator procedure. See footnote a for their level of significance designation.

about 20–40%. For the currencies, however, the difference is more varied, ranging from about 20–200%.

To provide additional evidence on the modified estimator's relative precision, the two estimators' spreads are related to variables implied by microstructure theory and shown empirically to be determinants of the spread. Specifically, the bid–ask spread is inversely related to the level of trading activity and directly related to the volatility of the underlying asset's price changes. Table III contains cross-sectional

Table III
RELATIONSHIP OF THE TWO SPREAD MEASURES' EFFECTIVE BID–ASK SPREADS TO TOTAL NUMBER OF PRICE CHANGES, PRICE CHANGE VARIABILITY, AND MONTH-TO-EXPIRATION[a]

	Modified Spread Estimator		Roll Spread Estimator	
	Coefficient	*t*-Stat	Coefficient	*t*-Stat
Intercept	10.675	3.30	8.329	3.08
Number of ΔP	−6.626	−2.71	−5.540	−2.72
$\sigma(\Delta P)$	1.338	4.26	0.666	2.54
Month-to-expiration				
−1	0.102	0.13	−0.353	−0.55
−2	0.177	0.54	0.170	0.62
−4	0.170	1.02	0.059	0.43
−5	0.160	1.14	0.124	1.06
−6	−0.148	−0.77	−0.141	−0.88
R^2	0.725		0.623	

[a]"Number of ΔP" is all price changes recorded on the CME *Time and Sales* database for a particular futures spread in month-to-expiration category j. Price change variability, $\sigma(\Delta P)$, is the standard deviation of all price changes in month-to-expiration category j. Sample size equals 24 spreads for each regression. If an individual spread estimate is negative, it is treated as being equal to zero in estimating the regression parameters.

regressions of the two estimators' spreads on the logarithm of the *total* number of price changes occurring in month-to-expiration j as a proxy for volume, which is unavailable, and price change variability. Months-to-expiration are also included as dummy control variables. Coefficients for the two trading activity variables have their expected signs and are statistically significant for both approaches, but the relation between spread and volatility is stronger for the modified estimator. This is reflected in the modified estimator's coefficient of determination being somewhat larger than the Roll method's R^2. The results thus appear to indicate that the modified approach offers some improvement over the usual Roll method.

Intercontract comparisons for the currency and interest rate futures are presented in Table IV. The DM front-month spreads tend to be larger than the SF spreads, while the reverse is true for the last two back months. A Box-M test indicates that only month −1 exhibits no statistical difference between the two contracts' spreads. The TB spreads tend to be larger than and statistically different from ED spreads. The overall difference in the spreads for all six months to expiration shows that, on average, the DM and TB spreads are about a half tick larger than the SF and ED spreads, respectively.

To investigate the significant noise (positive serial covariance) that adversely affects the ED spread estimates, the serial covariance of each calendar month's half-hourly price changes is first calculated and then classified by whether it occurs in a front or back month. Assuming the price changes' sample means is zero (and the sample means are quite small), these calculations are the mean cross products of each month's price changes. Next, the front- and back-month samples are divided

Table IV
INTERCONTRACT COMPARISONS OF EFFECTIVE BID–ASK SPREADS USING THE MODIFIED ESTIMATOR AND MEASURED IN TICKS BY MONTH-TO-EXPIRATION, 1983–1986 (ALL HALF-HOURLY TIME PERIODS)

	DM vs. SF Futures		TB vs. ED Futures	
Month-to-Expiration	**Difference**	***p*-Value (Box-M)**	**Difference**	***p*-Value (Box-M)**
−1	0.004	0.99	−0.202	0.00
−2	2.819	0.00	0.101	0.00
−3	2.558	0.00	−0.221	0.00
−4	0.160	0.02	1.226	0.00
−5	−0.595	0.00	0.614	0.00
−6	−2.201	0.00	1.730	0.00
Average	0.458		0.542	

into subsamples of negative and positive monthly mean cross products, and an overall mean cross product is determined for each subsample.

To assess the extent to which volatility may be influencing the spread estimates, the variance of *all* price changes also is estimated for the four subsamples. To gauge the extent to which information arrival may be influencing the spread estimates, the proportion of price continuations in each subsample is determined. A continuation is defined as two successive price changes in the same direction and is indicative of a time period experiencing a lagged price adjustment to information. Because TB and ED futures are usually affected by the same information, identical calculations are done for the TB contracts and compared to the ED results.[10]

From panel A of Table V, the absolute value of the negative mean cross-product is larger than the positive mean cross-product in the ED front months, but the reverse is true for the back months. Moreover, the individual monthly mean cross-products are negative in 40 of the 48 months; however, only 26 months are negative in the back months. Positive *s*cov months also tend to have a larger number of price changes, on average, which is consistent with information arrival. Compared to Eurodollars, the TB front and back months in panel B are better behaved. The absolute values of the mean cross-products are larger than the ED's when *s*cov is negative and are much smaller when *s*cov is positive. Furthermore, the TB front and back months have a similar and larger number of months for which *s*cov is negative. Like ED futures, monthly trading activity is higher when *s*cov is positive. Thus, the reason for the troublesome ED spreads in the back months seems to be the relatively common presence of positive serial covariance rather than infrequent periods of extremely large positive serial covariance. In other words, periods of positive serial covariance occur in a disproportionately greater number of months and in months

[10]While the SF front months also appear to be affected by significant noise, their spread estimates do exhibit the intuitively appealing "dipper" characteristic and two of the three spreads are negative and statistically different from zero under the Kendall test. Therefore, further investigation is focused on a comparison of just the ED and TB contracts.

Table V
MEAN CROSS-PRODUCTS, VARIANCES, AND PERCENTAGE CONTINUATIONS OF SUCCESSIVE (HALF-HOURLY) PRICE CHANGES FOR EURODOLLAR AND TREASURY BILL FUTURES BY FRONT AND BACK MONTHS, 1983–1986

	Front Months[a]		Back Months[a]	
	$scov < 0$	$scov > 0$	$scov < 0$	$scov > 0$
A. Eurodollar futures[b,c]				
Mean cross-product	−0.337	0.274	−0.275	0.358
Number of months	40	8	26	22
Avg. number of ΔP per month	222	246	210	224
Variance	4.55†	7.04†	5.17*	7.47*
% continuations	0.242*	0.318*	0.281*	0.339*
B. Treasury bill futures[b,c]				
Mean cross-product	−0.342	0.197	−0.420	0.229
Number of months	37	11	36	12
Avg. number of ΔP per month	203	233	188	212
Variance	4.43	4.32	4.98	5.55
% continuations	0.244†	0.285†	0.268†	0.305†

[a]Front months are months −1 through −3; back months are months −4 through −6. $scov < 0$ Is a subsample of calendar months whose individual mean cross-products of price changes are negative. $scov > 0$ Is a subsample of those calendar months for which the mean cross-products are positive.

[b]"Mean cross-product" refers to the overall average of the individual monthly mean cross-products, which are calculated under the assumption of a zero mean price change.

[c]Level of statistical significance in a test of equal variances or percentage (proportion of) continuations with an unequal number of observations for $scov < 0$ vs. $scov > 0$ is designated as follows: *1% and †5%.

with relatively high trading activity, which means these time periods receive more weight in estimating the spreads.

Returning to the ED results, both price variability and the proportion of continuations are considerably higher when $scov$ is positive than when it is negative. Regardless of whether $scov$ is negative or positive, back-month variances are higher than their comparable front-month values. Similar to the ED, the TB's proportions of continuations are higher but somewhat smaller if $scov > 0$. In contrast, the TB's price variability when $scov$ is negative is statistically indistinguishable from its variability when $scov$ is positive. Finally, ED variances are considerably higher than TB variances when $scov > 0$. Thus, the sources of the ED's positive serial covariance appear to be both relatively high price variability and lagged price adjustments to information arrival. To the extent that the TB spread estimates are influenced by positive serial covariance, the source appears to be lagged price adjustments rather than price variability.

Finally, to determine if there are any isolated periods of unusually large positive serial covariance, the individual mean cross-products are analyzed separately by calendar time and by month-to-expiration. Although the statistics are not reported here, the 1984 calendar year contains the primary sources of positive serial covariance in the ED's back months.[11] Seven of the 22 positive monthly mean cross-products occurring in the back months fall in the April–December period, and four are among the largest five for the entire 1983–1986 period. To determine the extent to which this unusual time period influences the spread estimates, those seven months with positive mean cross-products are deleted from the 48 months of price change data (16 months for each back month), and then the spreads are recalculated. In this case, all three back-month spreads become positive.[12]

CONCLUSIONS

Application of a modified version of Roll's (1984) spread estimator to transaction prices finds that the effective spreads for foreign currency and interest rate futures tend to follow a dipper-shaped pattern across months-to-expiration. Spreads are higher for back months, reach their lowest levels two to three months-before-expiration, and then rise slightly in the month before expiration. This pattern is consistent with spreads varying inversely to the level of trading activity. Spread magnitudes are about one tick ($12.50 for currency and $25 for interest rate contracts) for one to three months from expiration and about three to five ticks four to six months from expiration.

This modified approach appears to eliminate the statistical bias of the standard Roll estimator; however, it does not eliminate completely the occurrence of negative spreads. Nonetheless, a cross-sectional analysis of spreads related to two measures of trading activity indicates that the modified approach offers some improvement over the usual application of the Roll estimator.

Finally, the ED and related TB futures are examined more closely to determine why the ED back-month spreads are negative. The reasons appear to be excessive price variability and lagged price adjustments to information that produce significant periods of positive serial covariance, especially during 1984. While the TB futures spreads also are affected by positive serial covariance, the impact is much less significant and appears to be due only to lagged price adjustments.

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[11]The individual mean cross-products by calendar month and by month-to-expiration are available from the authors.

[12]The two largest positive mean cross-products, for instance, are found in the back months during May and July and are equal to 0.865 and 0.944 for months −5 and −6, respectively. During these months, rumors involving the Continental Illinois bank crisis and events surrounding major banks' troubled Latin American loans were prevalent. The resulting "flight to safety" caused Treasury bill rates to diverge significantly from ED rates, with the TED spread opening from about 50 basis points in January to 110 basis points by June. In addition, five of the 12 positive monthly mean cross-products in the TB back months occur in the July–December, 1984 period, and two are among the largest five. Interestingly, July also contains the TB's two largest positive mean cross-products, i.e., 0.681 and 0.652 for months −3 and −6.

In addition, 1984 is the most volatile interest rate period in this study. Short-term rates increased 200–300 basis points from January to June, peaked in September, and then fell over 300 basis points by December.

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