EURODOLLAR FUTURES PRICING

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ABSTRACT

This paper examines the pricing and arbitrage of the CMEX Eurodollar futures contact by employing daily spot LIBOR rates. The term forward rate differs significantly from the futures rate, especially 6 to 9 months before futures expiration. Moreover, the futures rate is consistently larger than the implied forward rate for 3 to 9 months before expiration. However, the relatively large size of the arbitrage bands at this point in time negate any arbitrage possibilities. The use of overnight spot rates to determine the forward rate shows very large deviations between the futures and forward rate, with the direction of the deviation based on the specific futures expiration. Use of the overnight spot rate would have provided very significant arbitrage profits for the time period studied. The pattern of term forward/futures deviations and the large profits available from using the overnight spot rate are unexplained phenomena.

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I. INTRODUCTION

Eurodollars are actively traded by international banks, with London serving as the center for large volume trading. Since 1982 Eurodollar futures have grown from a fledging contract to one of the two most active futures contracts in existence. However, no studies on CMEX Eurodollar futures pricing have been undertaken, apparently due to the difficulty in obtaining reliable historic data on the term structure of spot Eurodollar interest rates. This paper employs Bank of America (London office) LIBOR data (London Interbank Offer Rates) for the U.S. dollar by using daily overnight to one year rates to study Eurodollar futures pricing and arbitrage opportunities.

Section II of this paper explains how the implied forward rate is employed in the analysis. Section II proceeds to the specific pricing and arbitrage aspects for Eurodollar futures. Section IV examines the results and section V provides conclusions for the study.

II. IMPLIED FORWARD RATES

Eurodollar futures are based on a $1 million Eurodollar time deposit with a maturity of three months from the expiration of the futures contract. The interest rate associated with the cash settlement of the futures contract is based on the average offer rate from eight major London banks on the expiration day (the two highest and two lowest rates from 12 banks are discarded from the calculation).[1]

The pricing of Eurodollar futures contracts for the nearby, first, and second deferred contracts are examined by comparing the forward rates obtained from the daily LIBOR term structure data to the futures rates determined by the Eurodollar futures index value. Spot rates are available daily for overnight, 1 and 2 weeks, 1 to 3 months, 6 months and 12 months.[2] The forward rates are calculated by solving the implied forward rate equation in terms of the two relevant spot interest rates:

$$f = \{[(1 + R_2(\{T_1+T_2\}/365))/(1 + R_1(T_1/365))]-1\}(365/T_2) \qquad (1)$$

Where:

f = the one-period forward rate starting at time T_1

R_2 = the longer period spot rate of $T_1 + T_2$ days

R_1 = the shorter period spot rate of T_1 days

T_1 = the number of days from the current date until the futures contract expires.

T_2 = the number of days for the 3-month futures rate, typically 91 days.

London uses a 365 day year to calculate interest rates, while U.S. Eurodollar traders use 360 days. Since the rates employed are from London, 365 days are used here.[3] The three month time deposit associated with the futures contract varies from 90 to 92 days, depending on the specific quarter and year the futures contract expires.

Typically an exact maturity for the LIBOR spot rates is not available. In these cases a linear weighting of the two closest spot interest rates available from the data is employed to calculate R_1 and R_2. In fact, such a linear weighting scheme is practiced by

Eurodollar dealers for "off-the-run" dates. The linear weighted interest rate is calculated based on the two closest spot rates available from the LIBOR spot term structure rates:

$$R_i = S_{i-1}\ (w/D) + S_{i+1}\ (1 - w/D) \qquad (2)$$

Where:

R_i = the spot rate R_1 and R_2, for i = 1,2

S_{i-1} = the spot rate in the available LIBOR term structure with the next shortest maturity compared to R_i

S_{i+1} = the spot rate in the available LIBOR term structure with the next longest maturity compared to R_i

w = the difference in the number of days until maturity between S_{i-1} and R_i

D = the difference in the number of days until maturity between S_{i-1} and S_{i+1}.

Due to the time difference between London and Chicago, it is most appropriate to compare the opening futures rate to the available 2 P.M. LIBOR forward rate. The CMEX Eurodollar futures market opens at 7:20 a.m. Central time (previously the CMEX opened at 7:30 A.M.), creating a 30 to 40 minute time difference between the spot and futures rates.[4] The difference between the forward rate and futures rate also is employed to examine the effect of a large time lag on the results.

III. PRICING AND ARBITRAGE

A. Analyzing the Pricing of Eurodollar Futures

The accuracy of the pricing process for Eurodollar futures is determined by finding both the basis point difference and the percentage deviation from the implied forward rate, assuming no trading costs:

$$|BP_t| = |(F_t - f_t)| \tag{3}$$

$$|X_t| = |(F_t - f_t)|/f_t \tag{4}$$

Where:

$|BP_t|$ = the absolute difference in basis points between the futures and forward rates

$|X_t|$ = the absolute percentage deviation between the futures and forward rates

F_t = the futures rate based on the futures price at time t

f_t = the 3-month forward rate calculated from the term structure of LIBOR rates at time t (see equation 1).

The examination of the deviations from the forward rate follows the procedure in MacKinlay and Ramaswamy (1988) for the pricing of S&P 500 stock index futures, i.e. deviations are examined in terms of time until futures expiration and by determining the relationship between time and the size of the mispricing.

B. Arbitrage and Eurodollar Futures

The arbitrage process is an important ingredient for a successful futures contract. Arbitrage keeps the futures price within the transactions band of the "fair price". A breakdown of the arbitrage process can discourage hedging as well cause the overall volume on the contract to decrease because of the uncertainty of the pricing process.

Whether Eurodollar futures rates fall within the transactions bands around the implied forward rate is determined by ascertaining the bid-ask spreads for the spot and futures traders and the commission costs for these transactions:

1) Bid-ask spread for the cash transactions: large money center banks typically pay a bid-ask spread of 12 1/2 basis points for spot transactions with a maturity greater than one month and less than one year. A 6 basis point spread is employed for transactions less than one month. Spreads for other banks and for corporations are larger.

2) Bid-ask spread for the futures transactions: one tick is the typical spread for liquid Eurodollar futures expirations, with one tick = \$25 per \$1 million contract.

3) Commissions on cash transactions: There is a 1 1/2 to 3 basis point commission (depending on maturity) for each transaction. Here 1 1/2 is used for each of the two spot transactions. Other related costs are minimal, e.g. telephone charges.

4) Commissions on a Eurodollar futures contract: the commission for an institutional trade is \$12.50 per \$1,000,000 contract.

Overall, the total cost for an arbitrage between money center banks is 9 to 15 1/2 basis points (plus \$28), depending on the spot maturity. The size and persistence of any potential arbitrage profits in this study is determined for each expiration date and for the nearby, first deferred, and second deferred contract, i.e. from 0 to 9 months before futures expiration by calculating the following no-arbitrage bands:

$$P_f(1-C) < P_F < P_f(1+C) \tag{5}$$

$$C = S\ (T_1+T_2)/365 + \$28/P_f \tag{6}$$

Where:

P_F = the investment/loan value of the futures contract ($1 million per contract)

P_f = the value of the forward transaction

C = the transactions costs as a percentage of the forward transaction (i.e. in basis points)

S = the bid-ask spread plus commissions quoted in annualized basis points

When the futures price falls outside this band then arbitrage opportunities exist. Note that the size of the arbitrage band increases as the time to futures expiration increases. This increase is associated with the bid-ask spread and commissions of the cash trades, since these costs are quoted in terms of annualized basis points (and thus adjusted for the length of the transaction).[5]

The transactions required to generate an arbitrage position are as follows:

1) If futures are cheap in comparison to the forward transaction (i.e. F>f in terms of rates) then: buy the futures and create a forward liability in the cash market by borrowing long and lending short.

2) If futures are expensive in comparison to the forward transaction (i.e. F<f) then: sell the futures and create a forward asset by lending long and borrowing short.

The above transactions create pure arbitrage relationships, i.e. no funds from the financial institution are needed in order to execute the arbitrage. Vignola and Dale (1979) found that pure arbitrage describes the pricing process for short-term expirations of T-bill futures contracts.[6] Rendleman and Carabini (1979) compare forward and futures rates for the T-bill markets, finding differences of 24.6, 10.9, and 11.3 basis points for the nearby, first deferred and second deferred contracts, respectively. Kawaller and Koch (1984) show that the financing assumption is critical to determine how T-bill futures arbitrage is executed. They find that a series of overnight financing agreements best describes this pricing process. Here we examine the effect of a series of overnight investments/loans (depending on whether F>f or vice-versa) on the pricing and arbitrage results for Eurodollar futures.

IV. THE RESULTS

A. Pricing Relationships for Term Forward Rates

Table 1 shows the annualized absolute basis point deviations between the futures rate and the implied forward rate. These results show that the open futures rates deviate from the implied forward rates by an average of over 28.8 basis points for 6 to 9 months before futures expiration, 14.7 basis points for 3-6 months prior to expiration, and 10.2 basis points for the 0-3 month period before expiration. Standard deviations from the means are in parenthesis. The use of closing futures rates in part B of table 1 provides similar results; thus, the timing lag has little effect on the futures/forward differences. Table 2 shows the average absolute percentage deviations, which overcomes effects due to the level of interest rates. The average percentage deviations are 3.36%, 1.90%, and 1.47% for the 6-9 month, 3-6 month, and 0-3 month periods, respectively.

One factor which could affect these results is the discrete quoting system. Thus, LIBOR quotes are made in 1/16 ths, or 6 basis point intervals. A 6 basis point difference in a 12 month spot rate, with the short spot rate remaining the same, will cause a difference of 10 to 20 basis points in the forward rate (depending on the level and difference in the spot rates), although this effect is mitigated by the weighting system when the 12 month rate receives a weight less than one from interpolation. Moreover, the effect of discrete quotes should not be limited to one direction and therefore their overall effect on the means in tables 1 and 2 should be negligible (although the standard deviations would increase).

TABLES 1 AND 2 ABOUT HERE

Table 3 shows that the futures prices are consistently above the forward rates from 3 to 9 months, while the forward rates are larger for the 0-3 month period. Thus, the large deviations shown in tables 1 and 2 are associated with F>f.

TABLE 3 ABOUT HERE

B. Time to Maturity Relationships

Table 4 shows the results of a regression analysis to determine the relationship between the daily pricing deviations summarized in tables 1 and 2 and the time to futures expiration. Such a relationship can determine if the deviations are a function of time, and if so, the average relationship between time and the deviations.

MacKinlay and Ramaswamy (1988) found a significant relationship between time and the percentage deviations for the S&P 500 stock index futures. Table 4 shows that a strong relationship exists for Eurodollar futures pricing for the September 1985 to June 1986 contracts; however, this relationship breaks down for the two remaining contracts. Specifically, the average size of the deviations decline by approximately .12 basis points per day for the first four contracts, with a typical R^2 value for the opening prices of at least 50% for these expirations.

TABLE 4 ABOUT HERE

C. Arbitrage for Term Forward Rates

Table 5 provides the annualized per contract arbitrage profits, averaged over the daily observations for the relevant futures expiration and segregated by time until futures expiration. Only the profitable arbitrage observations are reported in the tables. Recall that the length of the total spot plus futures time period affects the size of the arbitrage band. Thus, the band of approximately 16 basis points (annualized) the day before futures expiration (i.e. a three month time span) increases to over 60 basis points nine months before expiration (a total period of one year).[7] The results in table 5 illustrate that few if any arbitrage profits are available, either by using opening or closing prices. These results, especially for the 6-9 month period before expiration, is due to the size of the transactions bands. Note that the September 1985 expiration included a period of a flat to upwardly sloping curve, which affected the arbitrage results.

TABLE 5 ABOUT HERE

D. The Use of Overnight Eurodollar Spot Rates

The financing rate has been an important factor affecting T-bill futures pricing and arbitrage, i.e. using the overnight rate provides the most accurate pricing results for the cost of carry model for T-bill futures. For Eurodollar futures pricing the overnight rate may be used for either a series of investments or borrowings; thus, the series of overnight rates R_o is employed here as a substitute for the short-term cash rate $R_1(T_1/365)$.

$$R_o = e^{rt} \tag{7}$$

Where:

R_o = the effective short-term spot rate over period T_1 when a series of overnight rates are employed

r = the overnight spot rate at the current date, which is compounded continuously[8]

t = $T_1/365$, i.e. the fraction of the year from the current date until the futures contract expires.

Tables 6 and 7 provides the pricing relationships for the Eurodollar futures when the effective overnight spot rate is employed in place of the short-term term spot rate. These results show extremely large deviations between the futures rate and the implied overnight forward rate. The 6-9 month period has deviations averaging 90.3 basis points, the 3-6 month period has deviations of 38.8 basis points, and the 0-3 month period has an average deviation of 14.7 basis points. The associated percentage differences are 9.92%, 5.01%, and 2.05%, respectively.

TABLES 6 AND 7 ABOUT HERE

Table 8 shows that f>F for the large majority of observations from September 1985 to March 1985,, which is the opposite relationship to the term forward rate results in Table 3. This phenomena could help explain the large pricing deviations for the term forward rates and the F>f results in tables 1-3, since for these expirations $f_o > F > f_t$ for f_t = the term forward rate and f_o = the overnight forward rate. Unfortunately, this relationship breaks down for the June through December 1986 contracts.

TABLE 8 ABOUT HERE

While international banks may be reluctant to employ a series of overnight spot rates because of the risk of a change in interest rates over the period, table 9 shows that using a series of overnight rates would imply annualized arbitrage profits of $4,500 to $15,000 for the 6-9 month period and $1,700 to $5,400 for the 3-6 month period. Even the 0-3 month arbitrage results provide annualized profits, although fewer opportunities are available. The (large) profits in the first three maturities occur because the overnight rate is often significantly below the long-term spot rate (an upward sloping term structure curve is relevant for most of the data employed here), causing large forward rates that are much greater than the futures rate.

TABLE 9 ABOUT HERE

Compounding the actual series of overnight rates over the time periods in question provides an ex-post effective short-term rate. Table 10 compares the expected annualized overnight rate to the actual annualized rate. The expected rate is typically higher than the actual rate, often by more than 30 basis points. However, the risk of significant changes remains on an ex-ante basis. In fact, a difference of 10 basis points for the overnight forward rate translates to a 39 basis point difference in the annualized futures versus forward results. Apparently, this risk causes international banks to forgo the expected profits available from using a series of overnight Eurodollar spot rates for futures arbitrage (plus the lower effective cost for the time period in question). Moreover, this illustrates a primary difference in the T-bill versus Eurodollar futures pricing, i.e. T-bill futures are priced based on the overnight repo rate, while Eurodollar futures are (poorly) priced based on the term LIBOR rate.

TABLE 10 ABOUT HERE

V. IMPLICATIONS AND CONCLUSIONS

The relevance and importance of a paper on the pricing and Eurodollar futures is related to the size of this market and because there are no other studies on the pricing of the CMEX Eurodollar futures contract. The extent and consistency of the pricing differences between the term forward rates and actual futures prices for data four to nine months before futures expiration is too large to be explained by timing problems, especially since similar results occur when closing futures prices are employed.[9] Moreover, the extremely large pricing deviations and arbitrage profits when a series of overnight rates is employed indicates that the overnight market is not employed by international banks for Eurodollar futures arbitrage. Why large consistent mispricing exists and why such traders do not use overnight spot rates for arbitrage transactions is a mystery.

FOOTNOTES

[1] While this averaging process could create differences between specific bank rates and the average, the competitive nature of the Eurodollar market causes any such differences to be insignificant. Specifically, since the futures contract does price the offer rate of the depositor of funds, i.e. the rate the buyer of the futures is willing to place funds in a Eurodollar time deposit, the averaging process only creates a discrepancy if the average deposit rate differs from the specific bank rate used to calculate the forward rates.

[2] Obvious errors in the spot rates are changed to an expected rate by examining the term structure and nearby daily observations for the spot rate. Overnight and 12 month rates which change by more than 40 basis points for <u>one day only</u> when the rest of the term structure does not change are altered to expected values, since such atypical rates have significant effects on the results and the observation most likely is a data error. In particular, overnight rates which are 50 basis points above the other short-term rates cause large "arbitrage profits." Typically one to three rates are changed per quarter.

[3] In any case, use of a 360 day year changes the results by only 1 basis point.

[4] Chicago and London switch to daylight standard time at different times in the year. In the Spring, there is about one month where the timing difference between the 2 P.M. spot and the futures open is 20 minutes. In the Fall there is one week where the

difference is 1 hour and 40 minutes.

[5] The bid-ask spread and cash commissions are considered over the entire period $T_1 + T_2$. Thus, even though the cash settlement of the futures is at the offer rate, the motivated spot investor of funds who desires to offset another spot transaction would still only receive the bid rate for cash.

[6] Vignola and Dale found that expirations of five to nine months are best described by quasi-arbitrage, i.e. when T-bills currently in a portfolio are employed for financing purposes. This change from pure to quasi-arbitrage pricing was related at the time to tax differences between the futures and cash instruments. However, the tax effect is no longer relevant for arbitrage considerations.

[7] Profitable opportunities less than $100 annualized are removed from the results, since it is unlikely that such opportunities will be executed by arbitrageurs due to timing risk and overhead costs.

[8] The use of continuous compounding in place of daily compounding makes an insignificant difference in the results.

[9] One may argue that the term rate mispricing is related to an insufficient number of months for the spot quotes compared to what is available to traders. Specifically, dealers often quote monthly spot rates, while the data employed here only encompasses quotes for 1 and 2 weeks and 1, 2, 3, 6 and 12 months. However, the linear interpolation employed here should approximate the quotes for the missing months.

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TABLE 1

Pricing Relationships for Eurodollar Futures:

Average Annual Absolute Basis Point Deviations

A. Opening Futures Prices

Contract Expiration	Time to Futures Expiration 6-9 months	3-6 months	0-3 months
Sept 85	31	23	9
	(10)	(10)	(5)
Dec 85	33	14	8
	(10)	(9)	(5)
Mar 86	31	12	8
	(10)	(8)	(7)
Jun 86	29	7	8
	(13)	(5)	(15)
Sept 86	36	24	22
	(19)	(16)	(19)
Dec 86	13	8	6
	(7)	(5)	(4)
Average	28.8	14.7	10.2

B. Closing Futures Prices

Contract Expiration	Time to Futures Expiration 6-9 months	3-6 months	0-3 months
Sept 85	33	21	9
	(12)	(12)	(6)
Dec 85	32	14	9
	(12)	(10)	(6)
Mar 86	32	13	9
	(12)	(8)	(7)
Jun 86	29	8	10
	(13)	(5)	(7)
Sept 86	35	24	22
	(18)	(16)	(18)
Dec 86	15	8	7
	(10)	(4)	(5)
Average	29.3	14.7	11.0

* Numbers in parenthesis are the standard deviation using the mean of the distribution.

TABLE 2

Pricing Relationships for Eurodollar Futures:

Average Annual Absolute Percentage Deviations

A. Opening Futures Prices

Contract Expiration	Time to Futures Expiration: 6-9 months	3-6 months	0-3 months
Sept 85	2.99	2.49	1.05
	(.93)	(1.01)	(.64)
Dec 85	3.64	1.65	1.01
	(1.16)	(1.14)	(.59)
Mar 86	3.55	1.46	1.02
	(1.18)	(.89)	(.83)
Jun 86	3.42	.91	1.13
	(1.56)	(.60)	(.77)
Sept 86	4.65	3.57	3.62
	(2.59)	(2.34)	(3.11)
Dec 86	1.88	1.29	.96
	(1.08)	(.87)	(.71)
Average	3.36	1.90	1.47

B. Closing Futures Prices

Contract Expiration	Time to Futures Expiration: 6-9 months	3-6 months	0-3 months
Sept 85	3.23	2.25	1.21
	(1.21)	(1.25)	(.75)
Dec 85	3.45	1.73	1.08
	(1.36)	(1.23)	(.73)
Mar 86	3.73	1.52	1.10
	(1.36)	(.98)	(.87)
Jun 86	3.47	1.04	1.44
	(1.57)	(.65)	(1.02)
Sept 86	4.46	3.46	3.59
	(2.47)	(2.42)	(2.97)
Dec 86	2.18	1.32	1.08
	(1.52)	(.74)	(.76)
Average	3.42	1.89	1.58

* Numbers in parenthesis are the standard deviation using the mean of the distribution.

TABLE 3

Direction of Forward/Futures Deviations

A. Opening Futures Prices: Number of Days F>f

Contract Expiration	Time to Futures Expiration*: 6-9 months	3-6 months	0-3 months
Sept 85	53	60	11
Dec 85	52	57	11
Mar 86	53	54	7
Jun 86	50	40	7
Sept 86	43	32	43
Dec 86	49	38	22

B. Closing Futures Prices: Number of Days F>f

Contract Expiration	Time to Futures Expiration*: 6-9 months	3-6 months	0-3 months
Sept 85	53	57	11
Dec 85	52	56	13
Mar 86	53	53	11
Jun 86	50	40	13
Sept 86	44	32	44
Dec 86	46	37	20

* The number of trading days available in each time period are:
6-9 mo.: 53
3-6 mo.: 63
0-6 mo.: 63

TABLE 4

Regression Results: Forward/Futures Differences

Versus Time Until Maturity

A. Opening Futures Prices

Contract Expiration	Basis Points X Coefficient	Basis Points R^2	Percentage Changes X Coefficient	Percentage Changes R^2
Sept 85	.123	.545	.01094	.462
Dec 85	.134	.544	.01381	.484
Mar 86	.131	.607	.01478	.568
Jun 86	.116	.461	.01286	.412
Sept 86	.001	.046	.00260	.005
Dec 86	.0003	.163	.00439	. 1 1 4

B. Closing Futures Prices

Contract Expiration	Basis Points X Coefficient	Basis Points R^2	Percentage Changes X Coefficient	Percentage Changes R^2
Sept 85	.129	.456	.01150	.375
Dec 85	.124	.465	.01276	.402
Mar 86	.136	.575	.01539	.548
Jun 86	.107	.396	.01155	.327
Sept 86	.0005	.039	.00196	.003
Dec 86	.0004	.171	.00553	.130

TABLE 5

Annualized Per Contract Arbitrage Profits for Eurodollar Futures:

Average Profits Per Observation

A. Opening Futures Prices*

Contract Expiration	Time to Futures Expiration: 6-9 months No. Days	6-9 months Profits	3-6 months No. Days	3-6 months Profits	0-3 months No. Days	0-3 months Profits
Sept 85	2	$ 241	1	$ 631	0	
		(64)				
Dec 85	0		0		2	$ 161
						(21)
Mar 86	0		0		1	
Jun 86	1	$ 323	0		1	$ 729
Sept 86	13	$1166	10	$1034	29	$2047
		(673)		(592)		(1295)
Dec 86	0		0		1	$ 814

B. Closing Futures Prices*

Contract Expiration	Time to Futures Expiration: 6-9 months No. Days	6-9 months Profits	3-6 months No. Days	3-6 months Profits	0-3 months No. Days	0-3 months Profits
Sept 85	6	$ 264	2	$ 767	1	$ 119
		(229)		(71)		
Dec 85	1	$ 114	0		4	$ 491
						(338)
Mar 86	3	$ 447	0		1	$ 660
		(72)				
Jun 86	1	$ 223	0		3	$ 403
						(176)
Sept 86	12	$ 970	11	$1013	27	$2150
		(449)		(723)		(1126)
Dec 86	0		0		2	$ 509
						(405)

* Numbers in parenthesis indicate the standard deviation of the profits, when arbitrage was available.

TABLE 6

Pricing Relationships Using Overnight Spot Rates:

Average Annual Absolute Basis Point Deviations

A. Opening Futures Prices

Contract Expiration	Time to Futures Expiration 6-9 months	3-6 months	0-3 months
Sept 85	182	56	18
	(95)	(55)	(16)
Dec 85	101	43	14
	(73)	(36)	(10)
Mar 86	73	33	12
	(50)	(28)	(11)
Jun 86	48	25	11
	(44)	(26)	(11)
Sept 86	69	52	26
	(54)	(45)	(18)
Dec 86	69	24	7
	(52)	(19)	(5)
Average	90.3	38.8	14.7

B. Closing Futures Prices

Contract Expiration	Time to Futures Expiration 6-9 months	3-6 months	0-3 months
Sept 85	179	60	17
	(94)	(57)	(15)
Dec 85	104	43	14
	(73)	(34)	(10)
Mar 86	72	34	12
	(50)	(28)	(11)
Jun 86	47	25	12
	(45)	(27)	(11)
Sept 86	67	51	26
	(54)	(45)	(16)
Dec 86	71	24	8
	(53)	(20)	(7)
Average	90.0	39.5	14.8

* Numbers in parenthesis are the standard deviation using the mean of the distribution.

TABLE 7

Pricing Relationships Using Overnight Spot Rates:

Average Annual Absolute Percentage Deviations

A. Opening Futures Prices

Contract Expiration	Time to Futures Expiration 6-9 months	3-6 months	0-3 months
Sept 85	14.06	5.19	2.18
	(6.17)	(4.30)	(1.90)
Dec 85	9.01	5.15	1.62
	(5.45)	(4.38)	(1.20)
Mar 86	8.17	3.90	1.54
	(6.03)	(3.57)	(1.39)
Jun 86	6.16	3.39	1.59
	(6.52)	(3.90)	(1.70)
Sept 86	9.90	8.32	4.22
	(9.32)	(7.91)	(3.00)
Dec 86	12.20	4.08	1.16
	(10.58)	(3.45)	(.89)
Average	9.92	5.01	2.05

B. Closing Futures Prices

Contract Expiration	Time to Futures Expiration 6-9 months	3-6 months	0-3 months
Sept 85	13.87	5.50	2.05
	(6.17)	(4.43)	(1.85)
Dec 85	9.29	5.06	1.69
	(5.34)	(4.28)	(1.30)
Mar 86	8.13	4.08	1.59
	(6.03)	(3.50)	(1.47)
Jun 86	6.13	3.33	1.72
	(6.63)	(4.00)	(1.74)
Sept 86	9.68	8.25	4.22
	(9.21)	(7.88)	(2.77)
Dec 86	12.51	4.02	1.28
	(10.68)	(3.53)	(1.14)
Average	9.94	5.04	2.09

* Numbers in parenthesis are the standard deviation using the mean of the distribution.

TABLE 8

Direction of Forward/Futures Deviations Using Overnight Rates

A. Opening Futures Prices: Number of Days F>f

Contract Expiration	Time to Futures Expiration* 6-9 months	3-6 months	0-3 months
Sept 85	2	10	15
Dec 85	9	20	10
Mar 86	16	26	11
Jun 86	35	41	26
Sept 86	42	44	42
Dec 86	42	49	31

B. Closing Futures Prices: Number of Days F>f

Contract Expiration	Time to Futures Expiration* 6-9 months	3-6 months	0-3 months
Sept 85	3	17	14
Dec 85	8	23	11
Mar 86	16	28	10
Jun 86	31	40	30
Sept 86	40	43	44
Dec 86	43	49	30

* The number of trading days available in each time period are:
6-9 mo.: 53
3-6 mo.: 63
0-6 mo.: 63

TABLE 9

Annualized Per Contract Arbitrage Profits Using Overnight Spot Rates: Average Profits Per Observation

A. Opening Futures Prices*

Contract Expiration	6-9 months No. Days	6-9 months Profits	3-6 months No. Days	3-6 months Profits	0-3 months No. Days	0-3 months Profits
Sept 85	47	$15169	31	$5429	19	$1091
		(8939)		(5186)		(1270)
Dec 85	36	$8175	29	$3317	12	$ 516
		(6026)		(2893)		(289)
Mar 86	32	$5060	18	$3065	6	$ 925
		(3728)		(1951)		(685)
Jun 86	17	$4683	9	$3228	5	$1529
		(4158)		(3216)		(914)
Sept 86	29	$5475	28	$5366	35	$1937
		(4678)		(3156)		(1262)
Dec 86	28	$5515	13	$1778	1	$ 938
		(3502)		(837)		

B. Closing Futures Prices*

Contract Expiration	6-9 months No. Days	6-9 months Profits	3-6 months No. Days	3-6 months Profits	0-3 months No. Days	0-3 months Profits
Sept 85	46	$15318	37	$4942	16	$1278
		(8516)		(5442)		(883)
Dec 85	38	$7916	28	$3327	12	$ 816
		(6273)		(2608)		(535)
Mar 86	28	$5809	20	$2930	6	$1121
		(3371)		(1811)		(1095)
Jun 86	16	$5223	10	$3201	9	$ 899
		(3958)		(3219)		(732)
Sept 86	30	$5061	29	$5123	33	$1940
		(4662)		(3204)		(1213)
Dec 86	29	$5532	13	$1909	2	$1119
		(3611)		(910)		(81)

* Numbers in parenthesis indicate the standard deviation of the profits, when arbitrage was available.

TABLE 10

Overnight Rates: Expected less Actual

(Basis Points)

Contract Expiration	Time to Futures Expiration 6-9 months	3-6 months	0-3 months
Sept 85	35.0	26.8	- 7.7
Dec 85	12.5	-14.5	- 4.6
Mar 86	- 4.4	6.3	12.2
Jun 86	46.6	59.4	13.8
Sept 86	99.0	51.1	30.3
Dec 86	66.4	30.5	- 7.3