Settlement Method of Eurodollar Futures and The Expiration Day Effects

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ABSTRACT

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The IMM Three-month Eurodollar Futures contract, which is presently the most widely traded money market contract in the world, is used by practitioners in many different ways. Basically, practitioners carry out the following four distinctive transactions in the Eurodollar futures market : Hedging, Arbitrage ,Speculation and Spreading. The settlement method used to settle the Eurodollar futures contract plays a crucial role in each of these transactions. For the hedger and arbitrageur, the degree of convergence present between the futures price and the spot price is essential to the effectiveness of such transactions; as well, as the amount price stability present around the time when the hedge or arbitrage is lifted. Whereas, for the speculator and spreader, the effect that the settlement method might have on the price behaviour of the futures contract around the settlement period could prove to be a profitable opportunity or the cause of adverse effects on positions taken near the settlement period.

Four times a year, the Eurodollar futures contract is cash settled to a final settlement price that is tied to the spot three-month LIBOR. The LIBOR used in the settlement is determined by the Chicago Mercantile Exchange after having surveyed various major banks within the last 90 minutes of trade. Such construction of a settlement index may be subject to distortion and the settlement value may not reflect true market conditions. This paper examines any abnormal change in the trading volume , Three-month LIBOR, daily and intraday volatility of Eurodollar futures prices around expiration days over a ten year period. As the expiration approaches, the trading volume of Eurodollar futures increases, especially the day before expiration. Even with the increased market activity, the survey of LIBOR at settlement does not have much impact on the Eurodollar futures market in terms of price volatility, and the LIBOR quotes obtained through the survey do not systematically differ from the LIBORs quoted on surrounding days. The settlement method of Eurodollar futures seems to work properly and is not subject to manipulation.

TABLE OF CONTENTS

TABLES

1. THE IMM THREE-MONTH EURODOLLAR TIME DEPOSIT FUTURES CONTRACT

1.1. History

The three-month Eurodollar time deposit futures contract listed on the International Money Market(IMM) division of the Chicago Mercantile Exchange(CME) , which today is the most widely traded money market contract in the world[1], was the product of considerable experimentation. As the spreads between private money market instruments and Treasury bills were shown to be substantially more volatile during various financial upheavals of the early 70's, the practice of using Treasury bill futures as a hedge for private short-term liabilities could prove to be less effective. As a result of this, futures exchanges realized the enormous benefit that could accrue to them in the form of revenue and prestige if they were able to effectively develop a futures contract on private short-term obligations.

By the spring of 1980, various future exchanges, including the CME, came up with the idea of a creating a futures contract that would call for the delivery of a domestic Certificate of Deposit(CD). The concept seemed very feasible given the fact that a very large secondary market existed for domestic CD's.

[1] In 1992, more than 60 million Eurodollar futures contracts were traded on the Chicago Mercantile Exchange and the average month-end open interest was more than 1.4 million contracts. With a face value per contract of $1,000,000, this represents an underlying commitment of more than $1.4 quadrillion!

Around the same time, various alternatives were being looked at in order to create an appropriate contract for the Eurodollar market, which was growing at an exponential pace. The idea of having a contract that would require the delivery of a Eurodollar CD was considered given the fact such a commodity had traded since 1966. Unfortunately, Eurodollar CDs represented a comparatively small slice of the Eurodollar market. On the other hand, Eurodollar time deposits made up a large part of the Eurodollar market but were not negotiable.

As a possible solution to this impasse, the concept of cash settlement was first concocted. The concept revolved around the idea of allowing the buyer and seller of a contract to exchange cash payments based on the changes in the value of the underlying asset instead of delivering the actual underlying instrument when the contract expires. For the Eurodollar futures contract this would imply the exchange of payments based on the changes in the market interest rate(LIBOR) associated with three-month Eurodollar deposits. At that time, there was no such thing as a cash-settled futures contract. As a result, a cash settlement procedure had to be developed from scratch. Because the idea was breaking new ground, the Commodity Futures Trading Commission's deliberations on the concept required considerable time. The Commission had to assure itself that the settlement procedure would not be subject to manipulation.

By the summer of 1981, domestic CD futures contracts were already listed for trading on the Chicago Board of Trade(CBOT), the New York Futures Exchange(NYFE) and the Chicago Mercantile Exchange(CME). Shortly thereafter, the three-month cash-settled Eurodollar time deposit futures contract was given approval by the Commodity Futures Trading Commission, and by the end of 1981, a three-month Eurodollar Futures contract was listed for trading on both the NYFE and CME with each contract having a slightly different cash settlement procedure.

Of the various private short-term futures contracts mentioned above, the only two that prevailed, as of the end of 1982, were the domestic CD futures contract and the Eurodollar futures contract that had been listed for trading on the IMM division of the CME. In the end, the CME most probably won the private short-term interest rate futures battle from the experience it had gained in trading the three-month Treasury bill futures contract since as early as 1976.

As the integration of the world money markets was stabilizing the spread between U.S. and Eurodollar CD rates it became apparent that the Eurodollar and the U.S. CD futures contracts were becoming nearly perfect financial substitutes for one another. The only differences came down to issues such as liquidity and deliverable supply. By the mid-80's, the U.S. CD market had never fully recovered from the depressing effects that were felt from the financial difficulties that had plagued various prominent financial institutions in the early 80's. The banks' credit problems made the CD market less homogenous, and as a result, players in the CD futures market became overly concerned with knowing just which bank's CDs they would receive if they took delivery.

Given the headaches caused by the uncertain quality of deliverable supply for the domestic CD contract, traders began to favour the cash-settled Eurodollar futures contract in order to skirt the problem of individual bank credit. For the Eurodollar futures contract, individual bank risk is circumvented since the settlement rate used to cash settle the contract is derived from taking an average of the different quotes provided by the banks surveyed by the CME. As of the end of 1984, therefore, Eurodollar futures trading had caught up and passed trading in CD futures. And by 1986, trading in CD futures represented a very small portion of the short-term interest rate futures market which prompted the CME to officially bury the contract in the following year. The three-month Eurodollar futures contract traded on the IMM division of CME had become by the mid-80's the most popular short-term futures contract in the world; so much so, that by 1985 , the three-month Eurodollar futures contract was more actively traded than the three-month Treasury bill futures contract and has been so ever since.

The rapid growth that had experienced the IMM Eurodollar futures contract and the unsettling of the U.S. CD market had prompted other futures exchanges around the world to also list their own Eurodollar futures contract. In 1982, the London International Financial Futures Exchange(LIFFE) list for trading a three-month Eurodollar futures contract that is cash-settled but has an option that permits the delivery of an actual three-month Eurodollar time deposit on the contract maturity date. Its cash settlement procedure, however, is not identical to the one used by the CME making the two contract less fungible. Consequently ,in 1984, the Singapore International Monetary Exchange(SIMEX) listed a Eurodollar futures contract that is identical to the one traded on the CME making them perfect substitutes for one another. Nonetheless, the IMM Eurodollar futures contract still remains,by a wide margin, to this date the most actively traded of the different Eurodollar futures contracts.

1.2. Contract Design

The IMM Eurodollar futures contract, which made its first appearance in December of 1981, was initially created as a means for managing the risks inherent in lending and borrowing Eurodollars. The contract has a nominal size of $1 million and is tied to the 90-day London Interbank Offered Rate (LIBOR), which is the interest rate at which major international banks with offices in London offer to place Eurodollar deposits with one another. Every one basis point move in the futures price(yield) is worth $25(= $1,000,000 X 0.0001 X 90/360). As you might have figured out by now, the underlying asset is a $1 million three-month Eurodollar time deposit, which is nothing more than a U.S. dollar deposit with a bank or bank branch outside the United States or with an international banking facility in the U.S.[2] It should be noted,however, that since the Eurodollar futures contract is cash settled, the "notional" principal amount of $1 million is never actually paid or received. The notional principal is only used to determine the change in the total interest payable on a hypothetical underlying time deposit. Basically, the contract is designed to protect future interest expense(income) on $ 1 million for 90 days from fluctuations in three-month LIBOR.

1.3. Price Quotation

Given that the LIBOR rate paid on a Eurodollar deposit is equivalent to an add-on yield since the depositor receives the face amount of the deposit plus an explicit interest payment when the deposit matures, Eurodollar futures prices are quoted as an index determined by subtracting the annualized future add-on yield from 100. Therefore, at any point prior to the expiration of the futures contract, the add-on yield imbedded in the Eurodollar futures price represents the interest rate that is expected to yield a Eurodollar time deposit that has 90-days left to maturity at the futures contract expiration date. Consequently, one can easily interchange the term LIBOR futures rate with the term forward rate; therefore, Eurodollar futures

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[2]The world's center for Eurodollar trading is London, but there are active Eurodollar markets in other parts of the world as well.

are deemed to be fairly priced if the following equation holds:

$$[1+r(0,T+90)(T+90/360)] = [1+r(0,T)(T/360)][1+(r_f(T,T+90)/4)]$$ [3]

where,

T = the number of days until the futures contract expires;
$r(0,T+90)$ = spot LIBOR rate for a deposit maturing in T+90 days;
$r(0,T)$ = spot LIBOR rate for a deposit maturing in T days; and
$r_f(T,T+90)$ = the theoretical annualized LIBOR futures rate.

Therefore, the theoretical annualized LIBOR futures rate can be expressed as a forward rate in the following manner:

$$r_f(T,T+90)[360/90] = [1+ r(0,T+90)(T+90/360)]/[1+ r(0,T)(T/360)] - 1$$

As such the theoretical futures rate can be easily obtained by plugging the two respective spot LIBOR rates in the equation and solving for $r_f(T,T+90)$. Having derived $r_f(T,T+90)$, one can now obtain the theoretical futures price by simply subtracting the theoretical annualized LIBOR futures rate from 100. Consequently, any significant deviations from the theoretical futures price lends itself to profitable arbitrage activity.

[3] A 360-day year is assumed and r represents an annualized rate. Furthermore, given we are assuming that the volatility of interest rates is constant over time and that no transaction costs are incurred in taking a position in the futures market or in the spot market,the theoretical futures price derived from this formula can only approximate the "true" theoretical Eurodollar futures price.

1.4. Contract Settlement

Four times a year[4], Eurodollar futures contracts are cash settled to a final settlement price that is tied to the spot three-month LIBOR. On the last trading day,which is deemed to be on the second London bank business day before the third Wednesday of the contract month ,the CME conducts two surveys, one at the termination of trading and the other at a randomly selected time within the last 90 minutes of trading. The following is the excerpt from the rule book of the CME:

> " To determine the LIBOR at either time the Clearing House shall select at random 12 banks from a list of no less than 20 banks that are active players in the London Eurodollar market. Each reference bank shall quote to the Clearing House its perception of the rate at which the three-month Eurodollar Time Deposit funds are currently offered by the market to prime banks. The two highest and two lowest quotes shall be eliminated. The arithmetic mean of the remaining 8 quotes shall be the LIBOR at that time..."

Because expiring Eurodollar futures trade between 7:20 a.m. to 9:30 a.m. on the last day of trading[5], the CME conducts its survey between 8:00 a.m. and 9:30 a.m.(or 2:00 p.m. and 3:30 p.m. London time). Armed with a total of 24 quotes of which 12 were obtained at a randomly selected time within the last ninety minutes of trading and the other 12 at the closing, the CME

[4] Expiration months for listed contracts are March, June, September,and December. As of February 1994, a maximum of 28 contracts are listed at any one time,making the furthest available delivery date 84 months in the future.

[5] On non-expiration days, the IMM Eurodollar futures trades from 7:20 a.m to 2:00 p.m.(Chicago time).

discards the two highest and two lowest quotes from each time surveyed, and then uses the remaining 16 quotes to calculate an average spot LIBOR,which is rounded to the nearest basis point[6]. This rounded average is then subtracted from 100 to determine the final settlement price for the expiring contract. Any expiring contracts that remain open at the close of trading are marked to market one last time against this final settlement price. As such the process of price convergence between the futures and spot market at expiration is forced by the futures exchange via its cash settlement procedure rather than natural market forces such as is the case for contracts that contain provisions for physical delivery. Consequently, the settlement method mentioned above plays a central role in the trading of Eurodollar futures. As a result, a large part of the empirical and theoretical discussions presented in this paper will revolve around the effects of using such a cash settlement procedure to settle the IMM three-month Eurodollar time deposit futures contract.

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[6]This may strike as a trivial point,but if you consider that each 1 basis point change in the price of Eurodollar futures contract is valued at $25, a bank with a net long or short position of several thousand contracts at expiration would be very much concerned with the fairness of the rounding procedure.

2. USES OF THE EURODOLLAR FUTURES CONTRACT

Before anxiously diving into a more elaborate discussion on the concept of cash settlement, it would be appropriate at this time to discuss the different ways practitioners use Eurodollar futures; since any empirical finding that might arise from cash settlement can be by itself both a result of the user's ways and an effect on the user's results.

There are four basic transactions that can be carried out in interest rate futures: hedging , arbitrage, speculation and spreading. Hedging and arbitrage always involve transactions in two markets, in cash and futures; whereas speculation and spreading is restricted to one, the futures market.

2.1. Hedging

Hedging can be defined as" buying or selling a position in futures markets to counterbalance an existing or anticipated position in the spot market"[7].The position in futures is therefore taken as a temporary substitute for an intended later transaction in the cash market. As such, a hedger that is long(short) spot will take an opposing short(long) futures position in order to reduce overall risk. For a hedger using Eurodollar futures, the primary focus is therefore on trying to reduce the risk caused by movements in LIBOR.

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[7]Kobold, Klaus (1986) "Interest rate Futures Market", p.32

Risk reduction is therefore possible if cash and futures prices move more or less in the same direction. In the case of Eurodollar futures, this relationship is present in the rates and not in the prices; such that if the spot LIBOR rises (falls), the futures LIBOR rate should more or less rise(fall) also. Given that the futures price is expected to equal to the current spot price plus any costs[8] associated with carrying the spot contract until the futures contract maturity date, one would tend to expect the Eurodollar futures rate and the Eurodollar cash rate to be positively correlated . In general, it is believed that spot and futures interest rates tend to move together[9] since the existence of riskless arbitrage activity between the spot and futures market will keep spot and futures prices in sync. Given Eurodollar futures prices are quoted as 100 minus the futures LIBOR rate, Eurodollar futures prices must therefore be negatively correlated with the spot LIBOR rate. Thus, for example, upward(downward) movements in LIBOR result in downward(upward) movements of Eurodollar futures prices.

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[8] In the interest rate futures market carrying costs basically consist of the rate paid for funds borrowed to buy the spot contract and transaction costs associated with buying the spot contract. Storage costs are negligible for financial assets such as Treasury bills and Eurodollar deposits.

[9] Kawaller,I.G. (1992) " Financial Futures and Options ", p.29.

2.1.1. Basic Types of Hedges

Two types of hedges are distinguished as basically forming the nucleus of various hedging strategies: a short and a long hedge. Each hedge plays a specific role in reducing the risk of an upward or a downward movement in price or rate in order to protect an underlying or anticipated position.

<u>Short hedge</u>

A short hedge is defined as " selling a position in the futures market to counterbalance an existing or anticipated position in the cash market"[10]. Given that a rise in rates causes prices of fixed-income securities to drop, to prevent a loss for someone holding long such securities a short hedge is appropriate. Protection comes about from the fact that when rates rise, prices in both interest rate futures and cash markets drop; and as such, gains realized from futures short selling activity are used to offset loses sustained in the cash market[11].

Eurodollar futures, however, are mainly used to hedge an anticipated position in the cash market rather than an existing one. Given that much of the activity in the Eurodollar market

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[10]Kobold,K.(1986) p.33

[11]The assumption is that movements between futures and cash prices are more or less parallel. If futures prices and cash prices are not parallel, then mutual offset is not attainable resulting in an eventual overall profit or loss.

revolves around the business of borrowing or lending funds, participants are mainly concerned with controlling the interest rate risks associated with future borrowing or lending requirements. Since short hedges are used to hedge against a rise in interest rates, a seller of a Eurodollar futures contract is actually protecting himself against a rise in the cost of borrowing funds for three-months in the Eurodollar market in the near future. As such, short hedging in Eurodollar futures allows an eventual borrower to lock a borrowing rate before the actual borrowing takes place. An example of how this works is illustrated below:

Today

A borrower needs $10 million for three-months starting two months from now. Suppose further that the three-month forward LIBOR for that date is 8.50 and Eurodollar futures contracts expiring in two months are trading fairly at 91.50 (= 100- 8.50).

Action

In order for a borrower to lock now the cost of funds for money needed in two months, he or she can take today either one of the two following actions:

1. Borrow $ 10 Million forward at 8.50 percent. At rate of 8.50 percent, the total interest on the loan at the end of three-month loan(five months from today) would be:

   $$ \$\ 212{,}500 = \$\ 10{,}000{,}000 \times [0.085 \times (90/360)] $$

   or;

2. Sell 10 Eurodollar Futures contracts at 91.50 today and borrow at the prevailing three-month spot rate in two months. Consequently, there are three possible outcomes that may arise with short futures:

In two months:

A. **Rates remained Unchanged** (90-day LIBOR = 8.50%)

- Futures contract settles at 91.50.
- No gain or loss arises from futures position.
- Borrower takes $10 million at 8.50%
- In three months, borrower repays $ 10,212,500(= 10,000,000 X [1 +.085(90/360))

Net interest expense = $ 212,500

B. **Rates rise**(90-day spot LIBOR = 8.80%)

- Futures contract settles at 91.20.
- Borrower gains $ 7500 from futures position (= -10 contracts short sold X -30 basis points drop in price X $ 25 per basis point).
- Borrower takes $ 9,992,500(= $10 million - $7500) at 8.80%.
- In three months, the borrower repays $ 10,212,335 { = 9,992,500 X [1 + .088(90/360)]}

Net Interest expense = $ 212,335

C. **Rates drop**(90-day spot LIBOR = 8.20%)

- Futures contract settles at 91.80
- Borrower loses $ 7500 from futures position (= -10 contracts short sold X 30 basis point rise in price X $ 25 per basis point).
- Borrower takes $ 10,007,500 at 8.20%
- In three months, borrower repays $ 10,212,654 { = 10,007,500 X [1 + .082(90/360)]}.

Net Interest expense = $ 212,654

As shown in the above example, depending on whether LIBOR rises or falls , the borrower sustains either a gain or a loss from the short futures position, which is tend either subtracted or added to the borrowing that takes place at the two month mark. It is this mechanism of subtracting a futures gain or adding a futures loss to the borrowing requirement at the time the actual borrowing takes places that the borrower is able to completely shield himself/herself from any of the positive or negative effects that arise from movement in rates[12] . As shown in the above example, whether LIBOR rose or fell by 30 basis points, the interest expense remained about the same as if the borrower had borrowed forward $10 million at a fixed rate of 8.50 percent. This comes about from the fact that gains from a short futures position result in a lower amount funds to be borrowed at the takedown date, when LIBOR was deemed to have risen. Losses in a short futures position are recuperated via an

[12] In order to keep the example as simple as possible, we assumed that gains and loses resulting from the futures hedge are received at the end of the hedged horizon(the two month mark). However, the practice in futures markets is to realize these gains or loses at the close of trading on a daily basis over the hedged period. This system of daily settlement in futures markets is called marking to market and is carried out through an intermediary body called the futures clearinghouse. Daily settlement consists of settling daily gains or loses in the form of variation margin payments. As such, these daily gains or loses result in a need to invest or finance these variation cash flows continuously over the hedged period. Consequently, depending on how volatile rates are during the period being hedged, the amount of contract that have to be sold or bought in order to effectively hedge against either rise or drop in rates will be different than simply 1 contract for every $ 1 million of position. Therefore, in order to keep our hedge ratios straight, all we need to know is the cost of money between today and the end of the hedge horizon.The technique used to take this into consideration is known as "tailing",which consists of adjusting the hedge ratio as the futures contract moves from today(t) towards it's expiration(T) by incorporating the possible changes that may arise in the interest rates attributed to the daily futures settlement losses or gains. Since gains and losses on futures position must offset those interest paid or received at date T+90, the appropriate hedge ratio with Eurodollar futures is thus $1/(1+R_{t+1,T+90})$. Consequently,, tailing becomes more relevant when interest rates are high and the hedging horizon is long.

increase in borrowing and financed at a rate that was deemed to have fallen. Consequently, by selling 10 Eurodollar futures contract today[13], the borrower was able to lock now the cost of

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[13] To keep things as simple as possible, we assumed a hedge ratio of 1; that is, for every $ 1 million worth of position to be hedged, one Eurodollar futures contract was bought or sold. Since, in the above example, the objective was to hedge $10 million worth of future borrowing need, a total of 10 Eurodollar futures contracts were sold today. However, this approach is partly responsible for the mismatch in the hedge, as shown by the net interest expense figures being slightly different from the one corresponding to the idea of borrowing forward $10 million today as a way to lock the cost of funds for future needs. Consequently, the hedge ratio mentioned above needs to be refined.

The first step in refining the hedge ratio is to determine what effect a basis point increase(decrease)in the forward three-month LIBOR will cost the borrower at payback(in five months). We call this effect the nominal value of a basis point and in the example above it is:

$$\$10(.0001/4)\text{million} = \$250$$

Consequently, for every one basis point increase(decrease) in the realized value of three-month LIBOR, the interest rate expense of the loan will increase(decrease)by $250 at maturity.

However, the key in calculating an accurate hedge ratio in Eurodollar futures is to keep in mind that gains in losses on the futures contract are realized immediately via daily settlement. As such, a one basis point rise in the forward Libor will cause an $250 increase in the expected interest expense cost at payback,but today it will produce a $ 250 gain on a short futures position. Consequently, the correct hedge ratio is found by determining the present value of a basis point in the forward three-month LIBOR. Naturally, the answer depends on how far away the future is. If we do this calculation when there is still five months until payback, the present value of a basis point on the loan would be:

$$\$\ 250/[1+R_5(150/360)]$$

where R_5 is the five-month spot LIBOR used for discounting.

If we assume that R_5 is equal to 8.50. Then, the present value of a basis point with five months to payback(loan matures) would be :

$$\$\ 250/\ [\ 1\ +\ .085(150/360)]\ =\ \$\ 241.45$$

borrowing $ 10 million dollars in two months. As such, one should realize that the decision to protect oneself from a rise in rates also implies the foregoing of a potentially lower borrowing cost if rates fall, rather than rise.

Long hedge

A long hedge is defined as " buying a position in the futures market as an opposite transaction to either an existing commitment to deliver a security at a future date in the cash market or a planned cash purchase"[14]. Given that prices of interest rate futures rise when the underlying rate of interest drops, a hedger who has bought an interest rate futures contract is protecting himself/herself from an eventual drop in the rate of interest associated with his existing or future cash position. As such, the gains obtained in the futures position will offset the losses sustained in the cash market resulting from a drop in interest rates. Given the emphasis is on shielding oneself from a possible drop in rates, one must come

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Therefore, given that value of one basis point change in price of Eurodollar futures is equal to $ 25 and that we are looking at the hedge problem today, five-month before the maturity of the loan, the appropriate hedge ratio would have been:

Hedge ratio = -$241.45/$25 = - 9.658 contracts

That is, we had to sell 9.658 contracts today instead of 10.This might look as a trivial point, but if you consider that if the hedged horizon was significantly longer, the appropriate hedge ratio would have been significantly smaller than 1 and the hedger would have overhedged. As such, there is a significant time dimension in Eurodollar futures hedging that can not be ignored by the hedger.

[14]Kobold,Klaus (1986) p.33

to the conclusion that the primary user of long interest rate hedges must be entities that have a commitment to purchase a given fixed-income security or lend funds to an eventual borrower. As such, a long hedge becomes useful for offsetting losses that arise either from a higher purchasing price for fixed-income securities or smaller return for funds to be lent out.

Since much of the activity in the Eurodollar market revolves around the lending or borrowing of funds, a long position in the Eurodollar futures contract becomes useful in reducing the risk that LIBOR will drop,which will translate in lower return for the entities lending activity. Consequently, since the underlying instrument is a three-month Eurodollar deposit, buying one Eurodollar futures contract today becomes a protection against a possible drop in the three-month LIBOR before the actual deposit is purchased. One should,however,not forget that for Eurodollar futures delivery never actually takes place since the contract is cash settled. As such, protection comes about via the mechanism of offsetting futures gains or losses with the losses or gains arisen from the cash position. Therefore, a long hedge in Eurodollar futures provides the user with the opportunity of locking today the return for one's anticipated investments or lending activities carried out in LIBOR-based markets.

Consequently, the illustration provided before for the short hedge, is also very much applicable to long hedges with the exception that the hedger as a choice between forward lending instead of forward borrowing and buying 10 Eurodollar futures with two months away from expiration instead of selling them. As such, gains on long Eurodollar futures position occur when LIBOR falls; whereas, losses come about when LIBOR rises. In the end,however, if one repeats this exercise, one will obtain exactly the same figures for the net interest expense under each scenario as the ones shown in the illustration on short hedges. As such, the decision to protect oneself from a drop in rates constitutes an acceptance in foregoing a potentially higher return if rates rise, rather than fall.

In sum, short and long interest rate hedges are established with the aim of reducing interest rate risk. The way in which hedgers establish futures positions to get protection against price changes depends on whether expectations are formed or not. A hedger who routinely hedges every outstanding or planned position in the cash market automatically is said to have not formed any expectations on price movements. The objective of such a hedger is centered on abolishing or reducing any kind of price risk by shifting it through the futures market to others who are willing to bear it. A routine hedger will therefore hedge all positions, even if a price movement may be at his advantage. Consequently, a routine hedger is willing to forego any eventual position gains in order to shield himself from having to form any expectations on interest rate movements. Contrary to routine hedgers, selective hedgers establish futures positions based on expectations of future price movements. A selective hedger will therefore only establish a hedge if he expects interest rate to change to his disadvantage. In the end, however, the decision to hedge, whether long or short, is very much a result of a hedger's expectation or lack of expectation on future price movements.

2.1.2. Advanced Hedging Strategies

A characteristic that is very much unique to the Eurodollar futures contract is the fact that interest in contracts that are many months away from expiration remains quite alive. In comparison to contracts such as stock index futures, where much of the interest is almost entirely concentrated in the nearest contract,Eurodollar futures trading is present in contracts being as much as 84 months away from expiration. A partial explanation for such interest is given by that fact that financial intermediaries had traditionally offered fixed-rate,longer-term loans that were financed by shorter-term liabilities(deposits). For example, a one-year, fixed-rate loan might have been financed by rolling over four three-month Eurodollar time deposits. While the rate earned was fixed, the rate paid was variable. As interest rates became more volatile, bank profits became more uncertain. Consequently, banks became very much interested in being able to protect itself from adverse movements in the cost for funding the loan over the life of the loan.

One way banks responded to this situation was to offer loans at interest rates that fluctuated with market rates. Although it did provide a natural hedge for the bank, the risk of interest rate changes were simply transferred to the borrower. The borrower was now left with the task of managing the uncertainty surrounding interest payments over the life of the loan. As such, borrowers of LIBOR-based bank loans became very interested in Eurodollar futures contracts that covered the different quarterly payments that were scheduled. However, some borrowers were still reluctant to take variable rate loans, which pushed banks to offer fixed rate loans and hedge themselves in the Eurodollar futures market against adverse movements in LIBOR over the duration of the loan.

In the end, however, what has most likely contributed the most to the growth of Eurodollar futures trading was the phenomenal growth experienced by the market for interest rate swaps during the last decade[15]. Most interest rate swap contracts specify payments contingent on three-or six-month LIBOR. As such, swap market dealers frequently use Eurodollar

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[15] An interest rate swap is a formal agreement between two parties to exchange flows based on the difference between two different interest rates. The most commonly traded swap requires one side to pay a fixed and the other to pay a floating rate. For the generic "Plain Vanilla" swap, which is the mainstay of the swap market, the floating payment is based on either three-month or six-month LIBOR. For this swap, periodic interest payments constitute the net,or difference, between the fixed rate and *floating rate obligations whereby* the resulting difference is passed from the party with the greater obligation to the party with the lesser obligation. It should be mentioned, however, that the floating rate used to calculate the resulting payment is set at a predetermined reset date that is three-month and two days before each payment date in the case of a swap based on three-month LIBOR. As such, *for* 1 year swap with quarterly payments based on the three-month LIBOR, payments are netted with the net quarterly payment equal to the swap's notional amount(e.g. $50 million) times [Fixed rate(90/360) - LIBOR(Days/360)], where Days is the actual *number of days between* payment periods and the Fixed rate is often quoted as a spread over Treasuries(e.g., Treasury note) with matching maturity. Therefore, if the LIBOR is higher than the Fixed rate at the reset date, the side paying the fixed rate will actually receive money from the side paying the floating rate at the payment date. Consequently, it is not surprising to find out that swaps are frequently used to offset preexisting exposures. As such, a borrower engaged in variable rate borrowing will want to be on the fixed rate paying side *of* a swap arrangement in order to protect his position from rise in short-term rates; and vice versa, *for* the fixed rate borrower. It should be mentioned, however, that swap contracts are also executed with the contracting parties having no prior interest rate exposure; making it a trading vehicle rather than a hedging instrument.

futures to hedge their position in interest rate swaps. The hedge is especially good if the rate reset dates for the swap correspond exactly or very closely to the settlement dates for Eurodollar futures.

Given that on each payment date, the amount of cash that actually changes hands with a generic swap is equal to the notional amount times the difference between the fixed rate and the LIBOR established at the corresponding reset date, for someone who is long the swap (that is, one who pays the fixed rate and receives the floating rate -LIBOR) will have to write a check to the side that is short(that is, one who receives the fixed rate and pays the floating rate) if LIBOR falls, since the fixed rate payment will exceed the floating rate one. As such, when LIBOR falls in a given period, a long position in a swap will sustain a loss equivalent to the resulting swap payment for the given period, which in turn becomes a position gain for someone who took a short position in a swap. Consequently, if you were long a swap that was tied to the three-month LIBOR, you would buy Eurodollar futures to hedge against the adverse effects of a drop in LIBOR on the value of the swap. Therefore, we can also confidently say that Eurodollar futures are sold to hedge a short swap position against possible rise in LIBOR.

However, in figuring out the amount of Eurodollar futures that must be bought or sold in order to hedge a long or short swap position, one must remember that an interest rate swap can be easily divided into two hypothetical securities. Therefore, one can treat a long(short) swap as if it was:

- a short(long)position in a hypothetical fixed-rate note with periodic coupon payments and a repayment of par at maturity;

combined with

- a long(short) position in a hypothetical floating-rate note with periodic payments tied to an index(LIBOR) and a repayment of par at maturity.

Thus, one can easily find the effect that a one-basis-point change in yields[16] has on the value of a swap directly from the change in the value of a hypothetical fixed-rate note from a one-basis-point change in the fixed rate and from the effect of a one-basis-point change in the floating rate(LIBOR)on the value of the hypothetical floating-rate instrument. Given that pricing fixed-rate notes or floating-rate notes is quite straightforward, finding the resulting effect of changes in interest rates on the value of a swap turns out to be a basic computational exercise, instead of a complicated derivation. Since a long(short) swap is equivalent to a short(long) position in the fixed-rate instrument combined with a long(short) position in the floating rate, one can find the value of one basis point change in yields for the swap by simply netting the present value of a long(short) fixed-rate note position from a change in the fixed rate with the present value of a short(long) floating-rate note position from a change in LIBOR. Thus, an appropriate hedge ratio for hedging a swap with Eurodollar

[16] We are assuming a parallel shifts in the yield curve.

futures over the hedge horizon would consist of simply dividing the resultant net present value of one basis point change in yields by the $25 value per futures contract for every one basis point change in LIBOR rates.

The way interest rate swaps or bank loans are hedged via the futures market is very much driven by the liquidity of contracts that expire in the distant future and the opinion one has about how the yield curve will shift. Overall, there are two distinctive methods mentioned in the literature on interest rate risk management that are used to hedge the risk of changes in rates over time: the stack hedge and the strip hedge.

Stack Hedge

A stack hedge consists of holding the number of contracts needed to hedge the swap or the bank loan over the hedging horizon all in the lead month. For example, a bank who intends to hedge today against changes in the quarterly funding cost for a $10 million one year loan, will in a stack hedge sell 10 contracts today for every scheduled quarter(40 contracts) of the nearest contract month and will rollover at or slightly before the expiration of the expiring contract all contracts needed to cover the remaining quarters in the hedged horizon into the nearest contract at that time. As you can see, a stack relies heavily on near-term contracts to hedge the risk of interest rate changes for distant quarters. As such, the effectiveness of a stack hedge is clearly determined by the movement in interest rates implied by the futures prices for various maturities.

Since in a stack hedge one holds the nearest contract as hedge for a distant quarter, the assumption behind a stack is that changes in rates corresponding to nearer maturities will behave as the further ones. Consequently, a stack hedge works well if the yield curve shifts over time in a parallel fashion. Furthermore, stacks are frequently used when there is not much liquidity in contracts that correspond to further maturities. For Eurodollar futures, liquidity remains very high for contracts with maturities as far as four years in the future;and therefore, Eurodollar stacking is most frequently used for hedging a quarter in a long-term swap or loan that is further than four year in the future.

Strip Hedge

A strip is simply a coordinated purchase or sale of a series of futures contract with successive expiration dates. The objective of a strip is to "lock in" a rate of return for a term equal to the length of the strip. For example, a strip consisting of contracts with four successive expirations would lock up a one-year term rate; eight successive contracts would lock up a two-year rate,and so on. As of February 1994, Eurodollar futures can be used to lock up a rate of return for a horizon as far as seven years in the future. As such, Eurodollar futures strips are frequently used by banks to hedge bank loans with maturities as far as 7 years against changes in quarterly funding rates(LIBOR) over the life of the loan. In addition, Eurodollar strips have become over the years one of the most favoured instrument for hedging LIBOR-based interest rate swaps. A Eurodollar futures strip with expiration dates being very close to the swap scheduled reset dates has been proven to be a very effective instrument in hedging against changes in the value of the swap from changes in LIBOR. It should,however, also be mentioned that Eurodollar futures strips can also be used as a replacement for LIBOR-based swaps; since both can be used to take on additional interest rate risk in hope of making a profit, or as an offset to an existing exposure. Consequently, Eurodollar futures strips are frequently used as substitutes for swaps if Eurodollar futures are priced in a way that it proves to be more advantageous to hold a position in a strip rather than in a swap[17].

The way Eurodollar strips are executed depends very much on one's opinion on how the yield curve shifts. If one is willing to assume parallel shifts, then spreading evenly the total number contracts, deemed as appropriate for hedging adverse changes in the value of a swap or bank loan over the hedged period, over the contract months in the hedge horizon proves to be more effective than a stacked hedge and entails less rolling

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[17]If Eurodollar futures prices are rich-above fair value-selling a strip is better than buying a swap. If Eurodollar futures are cheap, buying a strip is better than selling a swap. Furthermore, Eurodollar futures strips have been substantially cheaper to execute than interest rate swaps in the past several years. Bid/ask spreads and brokerage costs are found to be narrower and lower in the Eurodollar futures market. But more important, is the fact that Eurodollar futures are not subjected to the risk of default of the contracting parties as in a swap contract.

over as the hedge ages. However, if shifts in the yield curves are not parallel, both the stacked and the simple strip hedges fail to provide an effective hedge. In such a case, a more complicated strip must be used to hedge one's underlying position. The strategy consists of hedging each leg of a swap or of bank loan separately. For example, in a one year swap with four quarterly payments, the first leg represents the first payment period in three months; the second leg represents the second payment period in six months and so on. However, in a generic swap the first payment is fixed at the inception of the swap, and therefore, a strip will be used to hedge against changes in the cash flows for the second, third and fourth leg of a one-year swap given the uncertainty surrounding the value of the three-month LIBOR at the each corresponding payment reset dates. As such, in a complex strip, the total number of contracts used to provide an overall hedge is the same as in the stacked hedge and the simple strip hedge, but are distributed according to the present value of a one basis point change in the rate of interest for each leg of a swap or bank loan.

2.2. Arbitrage

Arbitrage is defined as the " simultaneous establishment of two opposite positions for the same security in two different markets"[18]. The motive is to earn a profit from the temporary

[18]Kobold, Klaus (1986), p.54

price distortions between the two markets.The arbitrageur will therefore purchase the security in the market with the low price and resell it immediately in the other market at a higher price. As such , arbitrage transactions are considered to be of very low risk since the positions are established simultaneously at prices known in advance.

Arbitrage transactions between cash and futures markets are of graat importance,since they keep prices in the two markets in line. Given that hedging is based on the assumption of an approximate parallel movement between cash and futures prices, if arbitrageurs did not keep cash and futures prices in line, hedging would be similar to speculation. Consequently, the existence of effective arbitrage activity between the cash and the futures market is of fundamental importance to the success of hedging in reducing risk[19].

2.2.1. The Fundamental No-Arbitrage Equation in Eurodollars

Eurodollar arbitrage trading strategies are somewhat different than those in commodities and other securities. A typical Eurodollar arbitrage trading strategy extends over longer period of time than arbitrage in commodities and other securities. Basically, Eurodollar arbitrage consists of entering into a futures contract and establishing or taking a Eurodollar

[19]Kobold, Klaus (1986), p.56.

time deposit at time t(today); with the futures contract expiring at time T and the Eurodollar time deposit maturing at T+90[20]. Consequently, the fundamental no-arbitrage equation in the Eurodollar market is deemed to be:

$$1 + R_{t,T+90} = (1 + R_{t,T})(1 + R^{t}_{T,T+90})$$

where,

$R_{t,T+90}$ = Eurodollar TD rate between t and T+90, set at time t

$R_{t,T}$ = borrowing and lending rate between t and T

$R^{t}_{T,T+90}$ = rate implied by the Eurodollar futures price at t, to be paid on a Eurodollar TD between T and T+90

An intuitive interpretation of this no-arbitrage equation is that the return on an investment between dates t and T+90 $(1+R_{t,T+90})$ must equal the return on an investment between t and T $(1+R_{t,T})$ that is reinvested from T until T+90 at rate locked in by the futures contract $(1+R^{t}_{T,T+90})$.

Given the quotation convention of the Eurodollar contract,[21]

$$R^{t}_{T,T+90} = \frac{100 - \text{Quoted future price at t}}{(100)(4)}$$

Therefore, if we plug in the future rate derived from the corresponding Eurodollar contract traded at time t into the no-arbitrage equation and an inequality arises, than an arbitrage

[20]For simplicity, we will assume that Eurodollar TDs are settled immediately. In reality, however, Eurodollar TDs are settled two days after the deposit matures. As such, interest on a 90-day Eurodollar TD will be paid or received on date T+92, not T+90.

[21]We divide by 400 because $R^{t}_{T,T+90}$ is a quarterly rate.

opportunity exist between the Eurodollar spot and futures market.

2.2.2. Arbitrage Strategies

Basically, there are two types of arbitrage strategies that are very much common to the Eurodollar market and other securities markets: cash-and-carry arbitrage and reverse cash-and carry arbitrage. Cash-and-carry arbitrage is used in situations where the arbitrageur wants to exploit an opportunity that arose from future prices being significantly above their fair values; whereas, reverse cash-and carry is associated with situations where future prices are significantly below their fair values.

<u>Cash-and-Carry</u>

A cash-and-carry pure arbitrage in the Eurodollar market would entail the following steps[22]:

1. At time t, borrow $\$[(1+R^{t}_{T,T+90})/(1+R_{t,T+90})]$ million that extends from t until T at the borrowing rate, $R_{t,T}$(LIBOR).

2. At time t, establish a $\$[(1+R^{t}_{T,T+90})/(1+R_{t,T+90})]$ million Eurodollar TD that extends from t until T+90 at the going rate, $R_{t,T+90}$(LIBID). At time T+90, this will yield

$$[\$(1+R^{t}_{T,T+90})/(1+R_{t,T+90})\text{million}](1+R_{t,T+90}) = \$(1+R^{t}_{T,T+90})\text{million}$$

[22]For simplicity, we are assuming that there are no transaction for undertaking an arbitrage strategy and the spread between the borrowing and lending rate is negligible.

3. At time t, sell a Eurodollar TD futures contract that expires at T.

4. At time T, borrow $ 1 million that extends from T until T+90 at the LIBOR and take any profits from the futures position. This locks in a borrowing rate of $R^{t}_{T,T+90}$, because any changes in LIBOR between t and T are offset by the futures profit.

5. At time T, pay back the loan taken out in step 1.

6. At time T+90, use the proceeds from the original Eurodollar TD in step 2 to pay back the loan in Step 4. The cash inflow of $\$(1+R^{t}_{T,T+90})$ million from the Eurodollar TD is equal to the $\$(1+R^{t}_{T,T+90})$ million cash outflow from the loan taken out at T.

Like all cash-and-carry strategies, this strategy creates a synthetic lending position in a T-bill.It has a price at t of $\$[(1+R^{t}_{T,T+90})/(1+R_{t,T+90})]$ million and a face value at T of $ 1 million. Consequently, if we refer back to the no-arbitrage equation in section 3.2.1, we realize that no-arbitrage opportunity will exist if the rate of return on this synthetic T-bill(the implied repo rate), $1 - [(1+R_{t,T+90})/(1+R^{t}_{T,T+90})]$ equals to the arbitrageur effective borrowing rate,$R_{t,T}$.
As such, cash-and-carry pure arbitrage profits will exist as along as the rate of return achieved from cash-and-carry lending(the implied repo rate) is greater than the arbitrageur cost for borrowing the funds needed to carry out the cash-and-carry pure arbitrage strategy.

Given that one is able to create a synthetic long position in a security that extends from t to T by taking a long position in a spot instrument that extends from t to T+90 and a short position in the relevant futures contract, the concept of cash-and-carry arbitrage is frequently used as an alternative for establishing long spot positions. In the case of the Eurodollar, a investor who wants to lend out funds in the Eurodollar market for T-t days will compare the Eurodollar rate for a deposit maturing in T-t days with the synthetic rate that can be earned if he would purchase a Eurodollar deposit maturing in [(T+90)-t] days and sell a Eurodollar futures having T-t days left to expiration. As such, if the rate achieved by the synthetic position is higher than the actual rate offered for a Eurodollar deposit maturing in T-t days, the investor will lend fund via the synthetic strategy instead of the spot market. This synthetic lending is known as a cash-and-carry quasi-arbitrage strategy because the investor will either take a position in the actual spot or in the synthetic spot, but not in both as in the pure cash-and-carry arbitrage stra.egy.

__Reverse Cash-and-Carry__

Reverse cash-and-carry pure arbitrage entails transactions that are simply the opposite of the ones mentioned for the pure cash-and-carry arbitrage strategy:

1. At time t, lend $\$[(1+R^{t}_{T,T+90})/(1+R_{t,T+90})]$ million that extends from t until T at the lending rate, $R_{t,T}$(LIBID).

2. At time t, take $\$[(1+R^{t}_{T,T+90})/(1+R_{t,T+90})]$ million Eurodollar TD that extends from t until T+90 at the borrowing rate, $R_{t,T+90}$(LIBOR). At time T+90, this will cost

$$[\$(1+R^{t}_{T,T+90})/(1+R_{t,T+90})\text{million}](1+R_{t,T+90}) = \$(1+R^{t}_{T,T+90})\text{million}$$

3. At time t, buy a Eurodollar TD futures contract that expires at T.

4. At time T, establish $ 1 million Eurodollar that extends from T until T+90 at the going rate at that time and take any profits from the futures position. The long Eurodollar TD futures contract entered into a time t will lock in the rate earned, $R^{tT,T+90}$.

5. At time T, receive proceeds from the funds lend out in step 1.

6. At time T+90, use the proceeds from the lending at time T in Step 4 to pay back the initial funds received at time t in Step 2 . The cash inflow of $\$(1+R^{t}_{T,T+90})$ million from the Eurodollar TD establish at time T is equal to the $\$(1+R^{t}_{T,T+90})$ million cash outflow from the Eurodollar loan taken out at time t.

This creates a synthetic borrowing position in a T-bill. The synthetic borrower will receive $\$[(1+R^{t}_{T,T+90})/(1+R_{t,T+90})]$ million at time t and pay back $ 1 million at time T. Consequently, an arbitrage opportunity exists if the reverse cash-and-carry synthetic borrowing rate(implied reverse repo rate), $1 - [(1+R_{t,T+90})/(1+R^{t}_{T,T+90})]$, is smaller than the arbitrageur lending rate, $R_{t,T}$. In such a situation, funds to be lent out can be obtained more cheaply by borrowing through the reverse cash-and-carry instead of in the spot market.

As in the cash-and-carry strategy, we notice that in the reverse cash-and-carry strategy one can create a synthetic short position in a spot contract that extends from t to T by taking a short position in a spot contract maturing in [(T+90 -t)] days and buying a futures contract that expires in T-t days. As such, the concept of reverse cash-and-carry strategy, is frequently used as an alternative in establishing short spot positions. Consequently, a borrower who wants to borrow funds in the Eurodollar market for T-t days will compare the rate that is being offered in spot market to the synthetic borrowing rate than can achieved by borrowing funds in the Eurodollar market for [(T+90)-t] days and buying a Eurodollar futures contract maturing in T-t days. As such, if the synthetic borrowing rate is lower than is currently being offered in the spot market, the investor will borrow synthetically instead of directly into the spot market. As in the case of the cash-and- carry quasi arbitrage transaction mentioned perviously, one will take a position either via the synthetic spot or the actual spot market, but not in both. This synthetic borrowing is, therefore,known as a reverse cash-and-carry quasi-arbitrage strategy.

Since no net investment is required to execute either the cash-and-carry pure arbitrage strategy or the reverse cash-and-carry one, arbitrageurs will continuously exploit these riskless profit opportunities until it they are eliminated by the market pressures that arise from arbitrage activity. In the case of the pure cash-and-carry strategy, the arbitrage activity will have the following effect:

1. The cost of borrowing will rise as arbitrageurs demand to borrow more.

2. The price of a Eurodollar TD futures contract with T-t days left before expiration will fall due to the selling pressure from those engaging in the cash-and-carry strategy.

3. The rate on Eurodollar TD deposits will drop from an increase in Eurodollar lending from those engage in cash-and-carry arbitrage activity.

Whereas, market pressures from reverse pure cash-and-carry arbitrage will result in the following effects:

1. The rate earned from lending activity will drop as result of an increase in the desire to lend out funds from those engaged in reverse cash-carry-strategy

2. The price of a Eurodollar TD futures contract with T-t days left before expiration will rise due to the buying pressure from those engaging in the reverse cash-and-carry strategy.

3. The cost for borrowing in the Eurodollar market will rise as arbitrageur demand to borrow more.

By visually comparing the resulting effects that arise from market pressures associated with both cash-and-carry and reverse cash-and-carry arbitrage activity, one realizes that the most fundamental difference between these two strategies revolves around the effect that these strategies have on future prices. Both strategies play a crucial role in restoring equilibrium in futures markets. In the case of cash-and-carry arbitrage, overvalued future prices are brought back in line as the selling activity causes future prices to drop; whereas, the buying pressure from a reverse cash-and-carry strategy causes undervalued future prices to rise. As such, the existence of arbitrage activity ensures that prices, whether in the spot or futures market, are kept at levels that are considered to be fair and that the relationship between spot and futures market remains in sync.

As was mentioned by Burghardt et al.(1990) Eurodollar futures prices seldom are more than 10 basis points out of line with their theoretical fair value. The reason is partly due the fact that banks, who are major borrowers and lenders of funds, usually operate on extremely thin profit margins; and therefore, are very much interested in exploiting situations that could reduce the cost of funds or raise the rate of return on investments by only a few basis points. As such mispriced futures represent a valuable and low risk opportunity for bankers to improve their bottom lines. Consequently, banks are willing to exploit deviations that might emerge between the cash and futures market even if the degree of mispricing is small. As a result of this well developed arbitrage activity, Eurodollar futures tend to be in line with their theoretical fair values.

2.3. Speculation

Speculation means the purchase(sale) of a position and later re-sale(re-purchase) with the intention of profit from an intervening price change[23]. Unlike a hedger or arbitrageur, a speculator establishes only a position in the futures market. As such speculators engage in futures trading on the expectation that they can predict prices better than the market and thus profit from the expected price change.

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[23]Kobold,Klaus (1986),pp.52.

Consequently,a speculator expecting short-term interest rates, to decrease and thus prices to rise would buy the Eurodollar futures contract, if the futures price does not yet reflect this expected price change.

Speculators basically form their expectations about future price changes either by adopting a fundamental view of markets or a technical one or both. Fundamental analysis consists of using economic news and data to decide on which position to take in the futures market; whereas, technical analysis is more geared towards using barometers such as past prices, volume and open interest figures to form expectations. No matter what method is used, what is important to note is that speculators are willing to take an open position in the futures market. This willingness implies that speculators facilitate risk shifting from one market participant to another by accepting to take the opposite position - given futures trading is a zero-sum game - in the hope of a profit. In other words, a hedger who wants to shift the risk of a rise in interest rates will sell a futures contract to a speculator who is betting that interest rates will fall. Speculators therefore contribute to the futures market liquidity which is of fundamental importance to the effectiveness of hedging transactions.

2.3.1. Types of Traders

Besides public speculators, there are professional traders,known as locals, who own seats on a futures exchange and trade for their own behalf. Locals are roughly divided into three categories: scalpers, pit traders ,and floor traders[24]. The three categories mentioned are distinguished by the period of their speculative engagement.

<u>Scalpers</u>

Scalpers try to profit from positions held for short periods of time. They often work on the principle that although there is a generally stable equilibrium price, matching orders do not come in from the outside at precisely the same instant. As such orders to buy or sell will bring the price slightly away from its equilibrium value. Consequently, scalpers step in immediately to profit from the price change,brought by the next order which will bring back the price to its equilibrium level. As a result scalpers trade on price ticks[25] many times a day thus providing liquidity to the futures market, lowering the bid-ask spreads, and reducing transaction costs[26]. Consequently, scalpers will continue to be active players in an expiring

[24]Seigel, D.R & Seigel,D.F. (1990) " The Futures Market", pp.31-32.

[25]In the Eurodollar Futures the minimum price fluctuation or tick size is 1 basis points.

[26] Scholes, M.S (1981) pp. 267

futures contract until the very end by exploiting any disequilibrium that may occur as the contract comes to an end.Nonetheless, "scalping" is not a riskless strategy because if a fundamental move in the equilibrium price occurs scalpers can lose big.

Pit Traders

Pit traders are simply speculators who are like scalpers but take bigger positions and hold them longer. They are more likely to consider outside news than are scalpers, because they do not move as quickly. Pit trades are also known as day trades, given that they usually close out within the trading day. As such, day traders would mostly likely be interested in taking a position in an expiring contract in order speculate on the direction of the final settlement price.

Floor Traders

Floor traders are speculators who try to exploit cases in which intercommodity price relationships seem out a line. They must be full members who can trade in any pit on their exchanges. Floor traders are also known as position traders, since they take positions that last for several days or weeks. As such position traders are very sensitive to information releases that could give them an insight on the direction that price will take in the near future. Floor trades will most likely trade in the second nearest contract instead of the expiring one on the expiration day. Thus any valuable information that might be provided by the settlement procedure used to settle Eurodollar futures will be reflected by the floor trader via the second nearest contract.

2.4. Spreading

A spread is established by the simultaneous purchase and sale of related futures contracts. A spreader acts on the expectation that the price difference between the two contracts will change in one's favour,e.g. the price of the contract bought will increase by more(fall by less) than the price of the contract sold[27]. Therefore, spreading involves speculation on the relationship existing between related futures contracts. In the case of interest rate futures contracts, the spreader is speculating on the interest rate relationship. Consequently, the profit of spreading depends on the spreader's ability to anticipate relative price changes adequately. Although spreading sounds like speculating, it is less risky than pure speculation since no open positions are held and price movements of the two contracts are kept in line by hedging and arbitrage operations[28].

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[27]Kobold,Klaus(1986) p.57

[28]Kabold,Klaus(1986)p.57

2.4.1. Types of Spreads

Three different types of spreads can be distinguished in the literature: an interdelivery spread, an intercommodity spread, and an intermarket spread. Each type having a specific use in speculating on the relationship between futures contracts.

<u>Interdelivery Spread</u>

An interdelivery spread involves the purchase and sale of at least two different delivery months of the same contract. For the Eurodollar futures contract, this will involve,for example, the sale of a March contract and the purchase of a June contract. In an interdelivery spread, the spreader is speculating that the spread observed for the various contract maturities will change or is out of line. Given that Eurodollar futures rates behave very much like forward rates, interdelivery spreading in Eurodollar futures constitutes in itself a speculation on the movements of a LIBOR-based yield curve. Therefore,for example, if a spreader believes that the yield curve, currently upward sloping, is likely to flatten given that three-month spot rate is expected to rise more than the two-year spot rate, the spreader will want to sell the nearby Eurodollar contract and buy a two-year Eurodollar strip in order to exploit the anticipated shift in the yield curve[29]. Gains from interdelivery spreading are therefore very much a result of the spreader's ability to properly anticipate the direction of the rate change and the degree of movement that will be experienced by each component of the spread. Consequently, Eurodollar futures interdelivery contract spreading has become over the years a very popular way for speculators to play the yield curve given that contracts with maturities as far as 84 months into the futures are actively traded.

Intercommodity Spread

In an intercommodity spread two different securities are sold and purchased for the same month. One of the most popular intercommidity spreads in the interest rate futures market is the TED spread , which consists of taking opposite positions in both the T-bill futures and Eurodollar futures contract. Long and short positions in the TED spread are defined as follows:

Long the TED spread:

- Long T-bill futures
- Short Eurodollar TD futures

Short the TED spread:

- Short T-bill futures
- Long Eurodollar TD futures

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[29]Given a two-year strip consists of a total of eight contract with successive maturity dates, a total of eight nearby Eurodollar contracts must be sold in order to have a proper spread match.

where both contracts in the spread expire in the same month. This is possible because the Eurodollar TD and T-bill contracts both have the same expiration months;although, not the same expiration dates.

Consequently, the TED spread for a given month is quoted as

TED spread = T-bill futures price - Eurodollar TD futures price
=(100-Implied T-bill rate)- (100-Implied Eurodollar rate)
= Implied Eurodollar rate - Implied T-bill rate

Quoted TED spreads are believed to represent the risk premium associated with holding Eurodollar TDs instead of T-bills. Because Eurodollar TDs are issued by unregulated banks that do not carry deposit insurance, their rates are generally expected to reflect a risk premium over T-bill rates[30].

The TED spread is therefore used by investors who wish to trade on their views about the Eurodollar TD risk premium over T-bills. For example, if an investor believes that the current risk premium for Eurodollar TD's over T-bills is too low; and therefore, expects the premium between Eurodollar TD and T-bill rates to rise, will long the TD spread in order to profit from the expected increase in Eurodollar rates relative to T-bill rates. Whereas, an investor who expects the premium between

[30] It should be mentioned that this interpretation of quoted TED spreads is not completely accurate, for the implied Eurodollar rates are quoted on an add-on basis and the implied T-bill rates on a discount basis. Since discount yields are lower than their associated add-on yields, quoted TED spreads overstate any risk premium. Further, because the disparity between the discount and add-on yields increases with the T-bill yield, the risk premium overstatement is greater at higher yield levels.

Eurodollar TD and T-bill rates to fall would follow the opposite strategy of the long spreader and short the TED spread. As such, the effectiveness of a TED spread is very much as result of the investor's ability in anticipating relative price changes adequately.

In addition to the TED spread, the listing of the LIBOR futures contract, which is tied to the 30-day LIBOR rate, on the IMM in 1990, has made possible in trading LIBOR futures against Eurodollar futures-the LED spread. This trade relates strictly to the one-month and three-month points on the yield curve. Thus, if one expects the one-month rate to fall relative to three-month rate, one will buy the LIBOR and sell the Eurodollar futures. With opposite expectations, one will do the reverse.

Intermarket Spread

An intermarket spread consists of a sale and purchase of the same security traded on different exchanges. Given that Eurodollar futures are actively traded on three different exchanges- the IMM in Chicago, the LIFFE in London, and the SIMEX in Singapore- trading one Eurodollar contract in one market against one in another market has become quite popular. In addition to the extensive arbitrage activity occurring between markets, intermarket spreading is frequently used by investors as a way to exploit opportunities that result from differences between exchanges - e.g. trading hours, depth of market, political situation and etc. Therefore, the spreader in an intermarket spread is trading under the believe that a security traded at different exchanges will experience a price change of different magnitude on each exchange.

The three different type of spreads that were discussed have an important effect on the price structure of interest rate futures contracts, which is similar to the effects of arbitrage. While arbitrage keeps spot and futures prices in line, spreading keeps in alignment the prices for different maturities of the same security(interdelivery spread) or the price of different securities with the same maturity(intercommodity spread) or the prices of the same security traded at different exchanges(intermarket spread)[31].

[31]Kobold,Klaus(1986)p.58

3. THE SETTLEMENT METHOD FOR EURODOLLAR FUTURES

3.1 The Importance of the Settlement Method

One notices from the discussion elaborated in Section 2, on the various ways investors use the Eurodollar futures contract, that especially for the hedging and arbitrage transactions, the degree of convergence between the LIBOR and the Eurodollar futures rate each time a futures contract expires or is liquidated is crucial to the overall effectiveness of such strategies. Given that for the various examples provided on hedging and arbitrage in Section 2, we assumed perfect convergence between the LIBOR and the Eurodollar rate each time the futures contract expired. As such, a non-zero basis,for example, at the time a hedge is liquidated would certainly alter the results. With the size of the alteration would depend on the magnitude and direction of the basis at expiration. Consequently, a non-perfect convergence between future prices and spot prices could result in a loss in the effectiveness in achieving one's objective. Furthermore, the price movement of future prices and spot prices around expiration could provide opportunities for speculators and spreaders to speculate on the direction of prices or relative prices. Since for cash settled contracts the price convergence mechanism is forced by the settlement procedure, the technique used to settle the Eurodollar futures contract and it's possible effects on market behaviour is of crucial importance to the user of Eurodollar futures.

3.2. The Mechanics of Cash Settlement

The Eurodollar futures contract, as stock index futures contracts, is cash settled. Under cash settlement,the seller, who has not offset his or her contract by the end of trading, in effect gives the buyer a sum equal to the current economic value of the item less a sum the buyer originally had agreed to pay. Therefore, only the difference need be paid by the seller to the buyer,or by the buyer to the seller, according to whether the price rose or fell during the contract interval[32]. However, in practice, futures contracts are settled on a daily basis during the life of the contract by making periodic adjustments to the party's margin account, known as "settlement variations", as changes in future prices occur. Thus,when the contract expires, the final adjustment is the final "marking to market" of the contract's value at the end of the last trading day. The difference between the daily marking to market and the final marking to market at expiration, for the Eurodollar futures contract, is that for the expiring contract the final settlement price is based on a cash market index that is derived from a reading of cash prices via a market survey instead of the actual

[32]Paul, A.B."The Role of Cash Settlement in Futures Contract" Public Policy Research,Washington,D.C., 1985,pp.272

price at which the futures contract settled at the close of trade. Thus for cash settlement to work, traders of futures contract must have confidence that the final settlement price is a reasonably accurate reflection of current commercial values.

3.3. The Rationale for Cash Settlement

As was mentioned by Jones[1982], cash settlement is a feasible means for settling futures contract only if there is a "good" cash market price which can be used as basis for determining the futures settlement price. A "good" cash market price is said to be

(1) uniform,and represent an industry standard;
(2) well known and widely available;
(3) an accurate indicator of the "current value" of the commodity; and
(4) immune to manipulation.

However, cash settlement,if feasible, would be deemed necessary- that is, it would represent a considerable improvement over actual delivery- in situations in which the deliverable supply on contracts is low and the transaction costs of delivering the contract grade product on the cash or futures markets is high.

In situations where the deliverable supply is inadequate and the cost of making or taking delivery in the futures market is substantially larger than doing so in the cash market, future contracts that require physical delivery would experience a considerable amount of price imprecision during the closing period of trading[33]. For example, when faced with large delivery

[33]Paul,A.P.(1985),Washington D.C., pp.290-291

costs, shorts would rather buy in their futures position at a premium price in order to avoid the greater cost of making delivery. Such a rise in price of the maturing futures reflects a squeeze by the longs, which will result in a temporary disequilibrium between the futures and cash markets. Alternatively, if the supply of deliverable grade product is inadequate, the longs may receive an instrument of unwanted grade,lower quality, from the shorts. Disposing of such delivery could cause large losses. Faced with such prospects, the long might choose to sell out their futures positions at lower prices than otherwise would prevail - that is,"run from delivery." Consequently, because the cash settlement mechanism does not require actual delivery, cash settlement may reduce if not entirely eliminate the potential for squeezes on the futures market. Thus, if cash settlement is feasible and there is also a need for it, cash settlement is the optimal mechanism for settling a futures contract.

3.4. The Construction of a Settlement Index

Garbade and Silber[1983] show that construction of an accurate settlement index is crucial in designing a cash settlement futures contract. If the index reflects accurately the commercial value of the underlying commodity, cash settlement improves price convergence between futures and cash substantially(versus physical delivery). On the other hand, if the index is inaccurate or subject to manipulation, a preference for cash settlement is less stringent. The settlement index for Eurodollar futures is constructed by price(or rate in the case of Eurodollar futures) indications obtained from market participants. Price indications are neither transaction prices nor bid or offer quotations; they are merely "expert opinions" of the prevailing cash market price. The major problem with such price indication method is its susceptibility to distortion and lack of detection device to indicate whether a price indication is unrepresentative.

Dealers with positions in the market being settled in cash on the basis of their quotes may have a vested interest in the market, and thus may be suspect with regard to providing biased quotes. As a way to mitigate this problem of intentional bias reporting , it has been suggested that a sample of dealers should be contacted for quotes, one or more of both highest and lowest quotes should be eliminated since they are most likely to be the result of contamination, and the average of the remaining quotes should be used as the index. Also, different dealers should be contacted each time an index is specified, perhaps selecting a random sample from a larger group of market participants[34].

Such a procedure is known as a Symmetrically Truncated Mean(STM) settlement procedure. Lien[89],however, shows that the STM method does not entirely eliminate the possibility of quote

[34]Jones,F.J.(1982) Journal of Futures Market, pp.74

manipulation that arise from intentional biased reporting. The STM procedure is said to accommodate a stronger incentive for manipulation simply because any biased quote has a greater possibility of affecting the settlement price. However, the bias is said to be less significant if(i) the dealer has a smaller futures position, or(ii) the dealer incurs a greater cost when quotes differ from the settlement price, or(iii) the number of dealers providing quotes is large.

The scheme used for the cash settlement of Eurodollar futures, as mentioned in Section 1.4, is based on the premise that the market in the 90 day Eurodollar time deposits is sufficiently active and competitive to permit a reliable reading of the current interest rate on such loans by simply asking a sample of major banks, heavily engaged in such borrowing or lending, to give their own perception of the offer price as of any given time. To mitigate inaccurate and biased reporting, three devices are used: the random selection of reporting banks,the random selection of one of two time periods the market is to be quoted, and the casting out of extreme values in computing the index. Given the CME conducts two surveys consisting each of twelve banks randomly selected from a panel of twenty prime London banks, and discards the two highest and the two lowest quotes obtained from each of the two surveys, of which one survey is carried out at a randomly selected time within the last ninety minutes of trading on the last day and the other at the close of trading, the average obtained from the remaining 16 quotes,which is large enough number to dissipate any one bank's extreme quote, may reflect the "true" LIBOR prevailing at that moment. However, one should not forget that many banks engage heavily in Eurodollar futures trading and often all banks are in the same side. As shown in Table A., the settlement rate used to settle the Eurodollar futures contract was not representative of the true LIBOR in the beginning, but became more accurate over the years[35].

Table A.

Price Convergence of Eurodollar Futures Contract on Day of Expiration (Cash LIBOR at Settlement - Futures Settlement Rate)

	MARCH	JUNE	SEPTEMBER	DECEMBER
1982	0.07	-0.08	-0.03	0
1983	0.11	0.07	0.06	0.04
1984	0.01	0	0.01	0.11
1985	0	0.06	0.04	0.10
1986	0.02	0	0.02	0
1987	0	0	0	0
1988	0	0	0	0.02
1989	0.02	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	N/A	N/A

[35] The assumption is that having non-synchronous quotes in calculating the difference between the cash LIBOR rate quoted in the WSJ (3:00 p.m London time or 10:00 a.m New York time) on the futures settlement day and the settlement rate determined by the CME London bank survey (between 2:00 and 3:30 p.m London time or between 9:00 and 10:30 New York time) which is used to settle the expiring contract is negligible because the WSJ spot LIBOR quote falls comfortably in the middle of the CME bank survey.

3.5. The Implication of Distortion For Eurodollar Futures

The Eurodollar futures price is kept in line with its fundamental value because any deviation will be promptly arbitraged away by market participants. However, there is a slight imbalance in the way various participants can use Eurodollar futures. Banks can engage in Eurodollar futures arbitrage whether they are cheap or expensive. Nonfinancial institutions such as manufacturing corporations do not have the same facility. They can always extend liabilities by shorting financial futures if they are expecting higher rates. They also can arbitrage if futures are expensive by shorting Eurodollar futures and borrowing money. When the futures are cheap, however, nonfinancial institutions are at a disadvantage. They cannot arbitrage a price discrepancy by buying futures and lending funds because they are not lending institutions.

Thus, we have two classes of players on one side of the market (banks and nonfinancials) and only one on the other (banks). As a result, there has been a tendency for futures to be cheap. Banks as a class tend to be long more Eurodollar futures than they are short. In fact, Burghardt, et al. show that between 1987 and 1990 banks as a class tended to be long more Eurodollar futures than they are short[36].

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[36]Burghardt, et al look at the net positions of clients of Discount Corporation of New York Futures, most of whom are banks (Exhibit 2.10). The only exception of consistently long positions by banks was in 1989 when the CME added the third and fourth years of contract months. During this period, banks' net

If banks are usually long, they may be more inclined to give LIBOR quotes that are lower than the true rate so that the closing price will be higher. Furthermore, the CME asks each bank to quote "its perception of the rate", which is not necessarily the rate at which the bank is offering funds to any other bank. Thus, there is even greater incentive for the banks to provide inaccurate quotes. Of course there are a market forces that will discourage banks from providing inaccurate quotes. First, their reputation is at stake, and second, not all of the banks may be in the same position on the settlement day, thus conflicting quotes will mitigate the inaccuracy. Whether such a manipulation actually occurs can only be tested empirically. And such a test will provide the validity for the price indications method of settling futures contracts.

3.6. The Expiration Day

Extensive studies on the expiration day effects have been conducted on S&P 500 Index futures and options (Stoll and Whaley [1987, 1991], Chamberlain, Cheung and Kwan [1989], Herbest and Maberly[1990], Hancock [1993]). They document dramatic movement in stock market volume and/or prices on the expiration days of the contracts, and point to order imbalance from unwinding hedging/arbitrage position as a cause of such movement. In June

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positions were negative. What this suggests is that the newly listed deferred contracts may well have been expensive.

1987, the CME, the NYFE and the NYSE changed the expiration day of some index futures and select index options in an effort to reduce the impact of the triple witching hour. The later studies show that, since 1987, market activity on index contract expiration days have not been abnormal.

Unlike the index futures and options, any dramatic movement of LIBOR on the day of expiration would be dependent on the method of settlement instead of possible order imbalances. The survey of LIBOR on the settlement day is a way for participating banks to release their private information through their quotes. The intraday volatility of security returns can be caused by either private or public information. Because inflation and economic activity are the most important determinants of bond prices, publicly available information, particularly from government sources, may be expected to be the most important motivator of bond price volatility, rather than private information. Becker,Finnerty and Kopecky[1993], Ederington and Lee[1993],Harvey and Hwang[1991], Smith and Webb[1993] examine the intraday volatility of futures prices when new publicly available information is released, and find the volatility at the time of news release is higher than normal. In the present study, we study the conjecture that the release of private information on the settlement day influences the volatility of Eurodollar futures prices. In addition, the market's agitation around the LIBOR quoces provided by banks may also contribute to changes in price volatility.

4. EMPIRICAL ANALYSIS

4.1. Data

The data consist of daily Three-month LIBOR over an approximately 10 year period, March 1982 through June 1992, obtained from the Wall Street Journal. The WSJ publishes Three-month LIBOR quoted at 10:00am (3:00 p.m. London time). Since the time of quote made by the Chicago Mercantile Exchange on the day of settlement is between 2:00 and 3:30 p.m London time(9:00 and 10:30 a.m London time), the WSJ quotes falls comfortably in the middle. Thus, our Three-month LIBORs, on non-expiration days, are from the WSJ quotes and, on the expiration days, from the settlement price used by the CME. The daily volume and open interest figures of Eurodollar futures for the same period were obtained from data disks compiled by Commodity Services Incorporated. Data on the intraday price of Eurodollar futures were obtained from the *Time and Sales Data* tapes provided by the CME, which contain time and price data for Eurodollar futures contracts that were traded over a 10 year period - from June 1982 to June 1992. The ten year period covered by our study has forty two expirations. All of the forty two expirations have been on Mondays.

4.2. Expiration Day Effects

A. Trading Volume and Open Interest

Given that most positions held in Eurodollar futures would unwind before the expiration day, and that Eurodollar futures are cash settled; as such, there would not be any contract calling for delivery on the expiration day. Most of the expiring contracts would be settled or rolled over to the next one and the trading volume is not expected to be high on the expiration day.

Table I gives a detailed picture of the pattern of volume and open interest around the 42 expiration days for the Eurodollar futures contract between 1982 and 1992. The volume of Eurodollar futures has increased consistently over the 10 year period. To account for the steady increase in volume and open interest, we measure the relative volume and open interest over a twelve day window around the expiration day. First, for each expiration month, we add up the volume and the open interest figures of all outstanding futures contracts over the twelve day window; which consists of six days before and five days after the expiration day. Then, the volume and the open interest of each day is normalized by the mean volume and mean open interest for the twelve day window in order to produce the relative volume and relative open interest value. A twelve day window was chosen to derive relative values in order to cover a window that contained at least three Mondays and three Fridays and a good mix of volume and open interest patterns around expiration days.

Table J reports the average relative volume and open interest, RVOL and ROI, for the 42 expiration months over the 10 year period. Results for the 5 days before and the 5 days after the expiration days are shown in order to include two sets of Non-expiration Mondays because all of the expiration days were Mondays. Non-expiration Mondays are included because of possible weekend effects.

As shown in ROI, the open interest reduces dramatically after the expiration day because the most heavily traded contract ceases to exist after that day. Since volume is related to the size of its market, we need to control for the reduction in open interest. Consequently, a third variable, VOI/OI, which is the volume divided by the open interest, is computed. This variable measures the relative level of activity controlled by the size of the market. The two volume measures, RVOL and VOI/OI, show heavy trading activity one day before the expiration day but there is not much activity on the expiration day itself. As mentioned above, such low trading activity on the expiration day may have been caused by the short trading day for those days - two hours and ten minutes. Thus, most of the position unwinding would have occurred before the contract expires. The volume increase on the day before expiration and the reduction in volume on the expiration day are shown to persist throughout the 10 year period as shown in the two subperiods in Table I.

An unusual finding is the significant reduction in volume on the fifth day after expiration. Despite the little change in open interest, both relative volume and volume over open interest figures are much lower than those on the previous days. On the fifth day before expiration, the relative volume figure also show a slight reduction. Thus, there seems to be a pattern of reduction in volume on Mondays. If this Monday effect is counted, the reduction in volume on the day of expiration becomes less stringent. If we consider the short trading day combined with the Monday effect, the trading volume on the expiration day may not be as small as it seems.

B. Three-month LIBOR

The level of LIBOR has also changed substantially over the ten year period from 1982 to 1992. Thus, we need to normalize the rate to account for the time trend. In Table II, the first row shows the average relative level of LIBOR over the ten year period for five days before and five days after the expiration day. The relative LIBOR, or RLIBOR, is computed for each twelve day window around each expiration day by dividing each day's LIBOR by the mean LIBOR over a twelve day period. There is no significant change in the relative level of LIBOR, and remains that way in the following two subperiods.

The second row shows the average percentage change in LIBOR over the ten year period. The percentage change in LIBOR has been, on average, negative on the expiration days. There seems to have been a significant drop in LIBOR quotes used on the settlement from the quotes made on the previous days. When the sample is divided into two five year periods, the large negative percentage change occurs mainly on the first five year period after the introduction of Eurodollar futures.

Tests of differences in the mean and variance for the relative level and percentage change of LIBOR on Expiration Mondays and the preceding Friaays are reported in Tables III.A and B, respectively, In the twelve day window over the ten years, there was a total of five days that were banking holidays either in the U.S or in London, of which all five were non-expiration Mondays[37]. For the analysis on the change in LIBOR around expiration days, rate changes for holiday Mondays were replaced by rate changes for non-expiration Mondays preceding the holiday Monday in a situation where the holiday Monday preceded the expiration Monday, and replaced by the following non-expiration Monday rate change if the holiday Monday followed the expiration Monday. Based on the pooled t-test, Table III.A shows that the mean percentage change in LIBOR shows significant negative difference on Expiration Mondays compared to other Mondays(in the twelve day window), especially

[37]Holidays were held on the following days over the 10 years in the fifteen day window: 82-09-06,83-12-26, 87-09-06, 89-12-26, 89-12-25.

in the first five year period. The F-test results show that the variance of RLIBOR is significantly different on expiration Mondays compared to other Mondays.

Table III.B reports the tests of difference in mean and variance for the relative level and percentage change of LIBOR on the Friday before expiration compared to other Fridays(in the twelve day window). Neither the t-test nor the F-test show any significance throughout the testing period. Despite the increased market activity, the LIBOR does not show any significant change on the preceding Friday compared to other Fridays.

As a further test of the change in LIBOR we measure the extent to which LIBOR reverses on the next day after expiration. Based on Stoll and Whaley's three measure of price reversal, the following measures are used to capture any reversal around the expiration day. The first, which well shall refer to as a Type 0 reversal, is defined as follows:

$$Rev_{0t} = r_{t+1} \quad \text{if } r_t < 0,$$

$$Rev_{0t} = -r_{t+1} \quad \text{if } r_t \geq 0,$$

where $r_t([L_t - L_{t-1}]/L_{t-1})$ is the percentage change in daily LIBOR quotes at 10:00 am (Eastern Time) by the WSJ. On each expiration day, the rate is replaced by the rate that is used to settle the expiring Eurodollar futures. Although the settlement rate is quoted between 9:30 and 10:30 am (Eastern Time), the two types of rates are assumed to have little structural difference. A positive value for Rev_{0t} indicates a rate reversal, while a negative value indicates a continuation. Consequently, if Rev_{0t} is found to be positive than day *t* is said to be abnormal causing prices to reverse on the following day.

The second measure of reversal is as follows:

$$Rev_{1t} = |r_{t+1}| \quad \text{if } sign(r_t) \neq sign(r_{t+1}),$$
$$Rev_{1t} = 0 \quad \text{otherwise.}$$

In this case, Rev_1 is given a value of zero when r_t and r_{t+1} are of the same sign (whereas Rev_0 would have a negative value). Thus Rev_1 overstates the effects of reversal somewhat, because rate reversals due to new information (unrelated to the expiration) are fully reflected, whereas the failure of rates to reverse because of new information is not reflected[38].

The third definition of reversal we used was:

$$Rev_{2t} = |r_t| \quad \text{if } sign(r_t) \neq sign(r_{t+1})$$
$$Rev_{2t} = 0 \quad \text{otherwise.}$$

This measure, which we refer to as a Type 2 reversal, is based on the rate change that occurs on the expiration day. As such, it differs from the Type 0 and Type 1 reversals, which are

[38] Stoll, H. and Whaley, R., "Program Trading and Expiration-Day Effects," p. 26.

based on the following day. The Type 2 measure, unlike the others, provides information about the change in LIBOR immediately before expiration. Like the Type 1 reversal, it tends to overstate the information effect.

Table IV shows the average values for the above three types of reversals. On expiration days, the Type 0 reversal averages 0.01 percent over the forty two observations. Note that the magnitude of Rev_0 on the expiration day is not much greater than the others in the eleven day window. The average value of Rev_1, as expected, exceeds somewhat the average values of Rev_0 up to 0.32 percent, but rather small relative to the reversals on the surrounding days. The reversal for the previous day before expiration(day -1), however, shows large values, indicating that the LIBOR reverses on the expiration day. Accordingly, Rev_2 shows large values on the expiration day, averaging 0.69 percent over the forty two observation. Nonetheless, one should take note of the fact that the Rev_1 value is also large on Non-Previous Expiration Fridays(day +4); as well as, Rev_2 on Non-Expiration Mondays(day -5 , day +5). Which suggests that their might exist a weekend effect in the LIBOR market or that reversals occur on Mondays as a result of the abnormal volatility that is associated with U.S macroeconomic news releases, which are usually released on Fridays.

Test of differences in mean and variance for reversal of the percentage change in LIBOR on Expiration Mondays and the preceding Fridays are reported in Tables V.A and B, respectively. Table V.A reports that over forty two observation, Rev_0 is positive for expiration Mondays, but negative for non-expiration Mondays in the twelve day window; which reveals some abnormality on expiration days. In addition, Rev_2 is shown to be larger on expiration Mondays than on non-expiration Mondays. However, the t-statistic reveals that the mean reversal under Rev_0, Rev_1 and Rev_2 for expiration Mondays is not statistically different than non-expiration Mondays.

Table V.B reports that the mean reversal values, over forty two observation, for the preceding Friday before expiration are somewhat larger than on non-expiration Fridays(in a twelve day window), but the difference is statistically insignificant. More specifically, Rev_0 is 0.222 percent on the previous Friday before expiration compared to -0.015 percent on non-expiration Fridays. A positive Rev_0 therefore reveals that the preceding Friday LIBOR before expiration is abnormal. However, given REV_0 is based on the percentage change in LIBOR for the following day,which in this case is the expiration Monday, the abnormality could be a result of the LIBOR that was quoted for settlement on the expiration day.

When the testing period is divided in half, the sizes of reversal in all three types show large differences. In the first five year period, the sizes of Type 0 and Type 1 reversals on the previous day before expiration and the size of Type 2 reversal on expiration far exceeds those of other days. Table V.B reports that Rev_1 for the previous Fridays before expiration is significantly different than for non-expiration Fridays in the twelve day window. In the second five year period, however, the difference is not substantial. Furthermore, the magnitude of the reversals are lower in the second period than in the first. There seems to have been a large structural change in the reversal after the first five years of Eurodollar futures trading. The findings on both percentage change in LIBOR and rate reversals show that the LIBOR quotes for settlement had some distortion in the beginning but have become more accurate, or reflecting the market quotes better, over the years.

C. Daily Volatility Eurodollar Futures Prices

The CME records Eurodollar futures prices each time a transaction takes place at a new price[39]. The daily volatility of Eurodollar futures are measured with intraday price levels during the day because the CME records transactions only when there is a price change, and thus biases downward the volatility when the price changes are large[40].

In computing the volatility, we use quotes that are approximately 15 minutes apart, and we employ the nearest quotes available around the quarter-hour mark. Given the six hours and

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[39] The exchange's interest is to provide timely price information. Consequently, the observers record every change in price but do not separately record successive trades at the same price.

[40] The volatility is also measured with log of price changes but similar results are produced.

forty minutes trading period(7:20 a.m. to 2:00 p.m)[41] for each day, there are 28 price quotes and 27 price changes[42]. On the expiration day, the expiring contract trades only for two hours and ten minutes (7:30 to 9:30 am). Thus, the volatility on the expiring contract is based on 10 price quotes and 9 price changes. To account for changing price levels, the volatility is normalized by the mean price . The normalized price level volatility is defined as follows:

$$V_p = \frac{\sum_{i=1}^{N}\left(\sum_{j=1}^{28}(P_{i,j}-\overline{P_i})^2\right)}{N.\overline{P_i}.27}, [1]$$

where P_{ij} is the price on day i at time interval j and $\overline{P_i}$ is the mean price on day i. Since the expiring contract does not have enough number of observations to accurately measure the daily volatility, we also use 7½ minutes intervals so that we have twice as many observations on the expiration day. To have consistency, the 7½ minute intervals are used for non-expiring days to measure daily volatility for the first two hours and ten

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[41]Before November 15th of the year 1985, Eurodollar futures contract were traded from 7:30 a.m to 2:00 p.m

[42]The first observation is from price at 7:20 a.m., the second one is from 7:30, and the following observation are the prices at every 15 minute mark of the hour. If no transaction is recorded at the precise 15 minute mark, the price closest to the 15 minute mark is chosen.

For the time period before November 15th,1985, the first observation is at 7:30 a.m. and the following ones are at 15 minutes apart. Therefore, for this time period, there are 27 price quotes and 26 price changes on non-expiration days, and 9 price quotes and 8 prices changes on expiration days.

minutes of trading.

Table VI and Table VII report the average daily volatility of futures prices in the eleven day window around expiration for the four nearest contracts. Holidays , which happen to be on five non-expiration Mondays in the eleven day window, are, as in the analysis on the spot LIBOR, replaced by the closest non-expiration Monday following or preceding the holiday Monday in question. The volatility in Table V is based on prices in 15 minute intervals so that on non-expiration days, the number of prices observations is 28 and, on expiration days, the number is 10. Since the nearest contract expires on the settlement day, the daily price volatility of the nearest contract do not appear in the following five days. For the first contract, the volatility is much lower than the what is shown for the days nearest to expiration day in the six day window. Such low volatility on expiration could be explained by the relatively low level of activity on the expiration day due to the short trading hours. For the following three contracts, the volatility on expiration day is slightly higher than on non-expiration days but is much lower compared to the previous days. However, when we divide the ten year period into two five year subperiods, we notice that volatility on expiration days for the second, third ,and fourth nearest contracts is higher than other non-expiration days, except for the previous day, in the first five year period, but is lower in the second five year period.

What is noticeable in Table V is the high volatility in the day prior to expiration. All of these days fall on Fridays. As Becker, Finnerty and Kopecky report, most of the public announcement related to macro economic variables in the U.S are released on Fridays, and that the Friday return volatility is the highest of the week between 1986 and 1990. In the ten year period between 1982 and 1992, the daily volatility is still highest on Fridays, supporting the earlier findings.

Table VII reports the volatility based on prices from 7½ minutes intervals for the first two hours and ten minutes on both expiration and non-expiration days. Similar pattern is found here with not significantly different volatility on expiration days but highest volatility on the preceding Fridays. Since it is necessary to control for the day of the week effect, in the following analysis, the daily price volatility of Expiration Mondays are compared to those of Non-expiration Mondays and the volatility of the preceding Fridays are compared to those of Non-expiration Fridays.

Table VIII.A and B report the tests of any unusual change in mean volatility of Eurodollar futures prices on Expiration Mondays and the preceding Fridays, respectively, for all four nearest contracts. In these mean and variance tests of price volatility, a twelve day window around expiration days is chosen so that (the first two hours and ten minutes) price volatility from forty one Expiration Mondays and forty one Non-expiration Mondays are used(holiday Non-expiration Mondays in the twelve day window are replaced by closest Non-expiration Monday) for the expiring contract. For the next three contracts, forty one Expiration Mondays are compared to the surrounding eighty two Non-expiration Mondays.

For the first contract(the expiring contract), the volatility on Expiration Mondays is not significantly different from those on Non-expiration Mondays. In fact, the second five year period shows significantly lower volatility on Expiration Mondays compared to Non-expiration Mondays. For the other three contracts, the significance of difference in Expiration Monday volatility is low and spurious. As the results of F-test show, the variances of the volatility are almost all significantly different between Expiration Mondays and Non-expiration Mondays. In the first five year period, the variance of price volatility is much higher on Expiration Mondays than on Non-expiration Mondays, but in the second five year period, the variance is lower on Expiration Mondays. Such differences in the variance of price volatility across the twelve day window may be caused by the maturity effect: price variability increases as time to maturity nears[43].

Similarly in Table VIII.B,(the entire six hours and forty minute) price volatility from Fridays in a twelve day window around expirations are compared. For the expiring contract, forty one preceding Fridays and forty one other Fridays are used. For the next three contracts, forty one preceding Fridays

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[43]Samuelson[1965] was the first to theoretically formulate the maturity-effect hypothesis and several empirical studies confirmed the hypothesis.

and eighty two other Fridays are used. Table VIII.B reports that the daily price volatility on the preceding Fridays is also not significantly higher than those on Non-expiration Fridays. The F-test reports significantly different variance of price volatility on preceding Fridays. The overall results show that daily price volatility of Eurodollar futures is not abnormal both on the expiration day and on the day before expiration.

D. Intraday Volatility of Eurodollar Futures Prices

To examine intraday volatility, log returns, $\ln(P_t/P_{t-1})$, are calculated from Eurodollar futures prices of the expiring contract and the second nearest contract,respectively, for each 15 minute period over the trading day on each Monday[44] and each Friday in the twelve day window around expiration. As in the daily volatility examination, the price associated to the 15 minute time slot is deemed to be the tick price closest to the 15 minute mark. As such, for example, the 7:45 a.m. return represents the change in price in the 15 minute time span from 7:30 a.m. to 7:45 a.m.[45](Central Time). Consequently, the price

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[44]Holiday Mondays, which happen to be all a Non-expiration Monday,in the twelve day window are replaced by the Non-expiration Monday closest to the holiday Monday in question.

[45] After November 15th, 1985, Eurodollar Futures trading was moved to 7:20 a.m. from 7:30 a.m. Therefore, the 7:30 a.m. return represents the price change experienced over the 10 minute interval from 7:20 a.m. to 7:30 a.m. Consequently, before November 15th, 1985, price change results for the 7:30 a.m time

effect of an event that occurs at 7:30 a.m will be in incorporated in the return figure associated with the 7:45 a.m time slot.

As it was shown by Ederington and Lee[1993], Webb and Smith[1994], the volatility of Eurodollar futures prices at the opening is found to be significantly higher than any other time during the trading. More specifically, it was shown that the five minute interval from 8:30 a.m. to 8:35 a.m.(Eastern Time) experienced significantly higher volatility than any other five minute interval during the trading day. Ederington and Lee[1993] concluded that this higher volatility during the 8:30 a.m. - 8:35 a.m. interval is the result of the 8:30 a.m.(ET) announcement of the Employment report, Producer Price Index, Consumer Price Index, and Durable Goods Orders figures. Furthermore, it was shown that, although each of the above four announcements had significant effect on the volatility of Eurodollar futures prices, the employment report had the most significant effect on volatility, which happens to be released most of times on Fridays. As such, the higher volatility experienced on Fridays can be somewhat attributed to the clustering of macroeconomic news releases on Fridays.

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slot do not exist; the first return of the day represents the price change associated to the 15 minute interval starting at 7:30 a.m and ending at 7:45 a.m.

D.1. Model

Given that macroeconomic announcements are shown to have a significant effect on the volatility of Eurodollar futures prices, we must take into consideration the various macroeconomic announcements that occur on the expiration and Non-expiration Mondays included in the twelve day window around expiration; as well as, on the previous and Non-expiration Fridays, in order to examine if the expiration has any effect on Eurodollar futures price volatility. The method that will be used to investigate any abnormality in the intraday volatility of Eurodollar futures prices on the expiration day and on the previous day for the expiring contract and the second nearest contract compared to Non-expiration Mondays and Non-expiration Fridays, respectively, included in the twelve day window, consists of defining a series of dummy variables for the expiration day and the previous day, as well as for the time of day that a macroeconomic news release occurred on the Mondays and Fridays in the same twelve day window around expiration. Consequently, the following regression is carried out for data consisting of only the previous Fridays and the Non-expiration Fridays included in the twelve day window around expiration; and for data consisting of only the Expiration Mondays and the Non-expiration Mondays[46] included in the same twelve day window

[46]Holiday Mondays, which occurred on non-expiration days, in the twelve day window are replaced by another Non-expiration Monday closest to the holiday Monday in question.

around expiration:

$$|R_{jt}-\overline{R_j}| = a_{oj}+a_{1j}D_{1jt}+\sum_{k=2}^{K} a_{kj}D_{kjt}+e_{jt} \quad [2]$$

Where D_{1jt} = 1 if the Monday t(in a twelve day window around expiration) is an Expiration Monday in the case of the Monday analysis, or if the Friday t(in a twelve day window around expiration) is the previous Friday in the case of the Friday analysis. D_{1jt} = 0 if day t is neither the Expiration Monday, or nor the previous Friday. D_{kjt} = 1 if announcement k is made on the Monday t, or the Friday t, at the 15 minute interval j. D_{kjt} = 0 otherwise. Macroeconomic announcements that were considered, along with the time of day that the announcement is released and the number of announcements that were released on the Mondays and Fridays in the twelve day window around expiration over the ten year period under investigation, are listed in the Appendix. The dependent variable in our regression is the absolute value of difference between the actual return R_{jt} for the 15 minute interval j on the Mondays or Fridays in the twelve day window around expiration and the mean return $\overline{R}_j$ for the fifteen-minute interval j over all Mondays included in the twelve day window around expiration, or over all the Fridays included in the same twelve day window.

As noted by Ederington and Lee[1993], who based their reasoning on the evidence provided by Schwert[1989] and Schwert and Sequin[1990], that if log returns are normally distributed with constant mean but time-varying variance, $E|R_{jt} - \bar{R}_j| = (2/\pi)^{0.5}\sigma_{jt}$ where σ_{jt} is the standard deviation of returns in interval j on day t. Consequently, $(2/\pi)^{0.5}a_{oj} = 1.2533a_{oj}$ provides an estimate of standard deviation of returns in interval j when day t is not an expiration Monday ,nor a previous Friday, and no macroeconomic news has been released in interval j on day t. Whereas, $1.2533(a_{oj} + a_{ij} + a_{kj})$ is the standard deviation of returns in interval j when day t is a Expiration Monday, or a previous Friday, and a microeconomic announcement has been released in interval j on day t. Therefore, the a_{ij} and the a_{kj} coefficients provide a quantifiable measure of the effect that the Expiration Monday, or Previous Friday, and the macroeconomic announcement has on the standard deviation of returns in interval j. As such, if the a_{ij} and a_{kj} coefficients are respectively found to be positive and significantly different than zero, the expiration Monday , or the previous friday, and the macroeconomic announcement are both said to impact the market.

However, if the macroeconomic announcement always occurs on the Expiration Monday, or previous Friday, it becomes impossible to distinguish which event causes the increase in volatility. As way to mitigate this problem , and given the fact that the data consists of only the forty one expiration Mondays(previous Fridays) along with a total of eighty two Non-expiration Mondays(Fridays) that surround the expiration days over the ten year period, separate regressions are carried out for each forty five minute time span included in the trading day, with each time span having three fifteen-minute interval returns for each Expiration Monday (previous Friday) and Non-expiration Monday (Friday) included in the twelve day window over the ten year period. Consequently, on Expiration Mondays(previous Fridays) the D_{ijt} variable is equal to 1 for each of the three fifteen minute intervals included in the forty five minute time span; whereas, D_{kjt} variable is equa` to 1 for only the fifteen minute interval in which the macroeconomic announcement is released[47].

Furthermore, given that dependent variable $|R_{jt} - \bar{R}_j|$ is in absolute value term-that is, negative observations are transformed into positive values- using the Ordinary Least Squares method to estimate the coefficients will be clearly inappropriate. The dependent variable is said to be censored at y >= 0; and therefore, the distribution is shifted entirely into the positive quadrant. This transformation will destroy linearity, which happens to be one of the underlying assumption governing the ordinary least square method. The Tobit model, developed by Tobin, is a frequently used method for estimating parameters of situations in which the dependent variable is censored. The general formulation for a Tobit MLE model that represents the absolute value censoring used in this study is the following:

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[47] As it was shown by Ederington and Lee[1993], volatility from various macroeconomic announcements remains substantially higher than normal for roughly fifteen minutes, and than tapers off.

$$Y^* = \beta x + \epsilon$$
$$Y^* = |Y| \quad \text{if } Y < 0,$$
$$Y^* = Y \quad \text{If } Y >= 0.$$

The estimation of such a Tobit MLE model has become in recent years so routine, to the extent that it is now essentially on the same level of ordinary least square regression since it has been incorporated in so many computer packages.For our study, the Proc Life Reg procedure available on SAS was used to estimate the a_{oj}, a_{1j} and a_{kj} parameters of the absolute mean deviation regression mentioned previously . In addition, the Tobit MLE model has proven to have interesting properties with regard to effects of nonnormality, heteroscedasticity, and serial correlation.

Nonnormality

Nonnormality is an especially difficult problem in this setting. It has been shown that if the underlying disturbances(error term), ϵ_{jt}, are not normally distributed, the usual estimator is inconsistent. However, computer software available on Tobit models provide the user with the opportunity to define several distributions such as the exponential, lognormal, and Weibull. In the case of our study, we assume the disturbances to be normally distributed given that the number of observation included in the various regressions carried out far exceed the 100 observations assumed to be a definitive number for normality to be present under The Central Limit Theorem.

Heteroscedasticity

Heteroscedasticity was also shown to cause the estimator provided by the Tobit MLE model to be inconsistent. In our study, intraday returns over a 10 year period would certainly demonstrate a pattern that would be consistent with time-varying variance. As it shown in the Table B below, the variance of the disturbances are significantly different from one subperiod to other on both Mondays and Fridays for the expiring contract and second nearest contract.

Table B

Test of difference in Variance between the two five year subperiods based on 15 minute intervals returns for the whole trading day.

	Standard Deviation(Root MSE)			
Expiring Contract	Monday	F	Friday	F
June 1982- June 1987	0.00014	2.0*	0.00014	1.27*
Sept 1987 - June 1992	0.00007		0.00011	
Second Nearest Contract				
June 1982- June 1987	0.00018	2.25*	0.00017	1.13**
Sept 1987 - June 1992	0.00008		0.00015	

Goldfeld-Quandt Test : $F[n1 - K, n2 - K] = S^2_1/S^2_2$
If $F_{calculted} > F_{critical}$ - Reject hypothesis of equal variance between groups.
* Significant at the 1% level ** Significant at 5% level

As such carrying out the analysis on the total ten year period in one regression would provide inconsistent results. Although this heteroscedasticity could be eliminated by applying various weighting schemes, removing the heteroscedasticity will in itself remove any abnormal return variance that may be the result of the expiration day or the interval in which the announcement was released. Consequently, the analysis is divided into the following two five year period:

1. June 1982- June 1987
2. Sept 1982 - June 1992

Therefore, a regression consisting of the whole trading day in which 27 fifteen-minute interval returns are included, and a regression for each forty-five minute time span, which includes three fifteen-minute interval returns for each Monday(Friday) included in the twelve day window around expiration, is carried out for each subperiod separately. Table C below shows that the variance of the disturbances within the two five year subperiods is found to be substantially different from one period to another on Mondays only for both the expiring and second nearest contract in the first five year subperiod. Nonetheless, adjusting for this heteroscedasticity will remove any return variance difference that we are trying to find on the expiration day compared to non-expiration Mondays in the twelve day window. Consequently, we will continue our analysis by dividing the 10 year subperiod into two separate five year subperiods. Furthermore, Tobit MLE is said to be less sensitive to heteroscedasticity problems than the simple OLS regression.

Table C

Test of difference in Variance between the 2½ year periods in the two five year subperiods based on 15 minute intervals returns for the whole trading day.

	Standard Deviation(Root MSE)			
	Monday	F	Friday	F
Expiring Contract (June 1982- June 1987)				
June 1982- Dec. 1984	0.00017	1.89*	0.00014	1.27
March 1985 - June 1987	0.00009		0.00011	
Expiring Contract (Sept.1987 - June 1992)				
Sept. 1987 - Dec. 1989	0.00007	1.17	0.00011	1.22
March 1990 - June 1992	0.00006		0.00009	
Second Nearest Contract (June 1982- June 1987)				
June 1982- Dec. 1984	0.00022	2.2*	0.00020	1.0
March 1985 - June 1987	0.00010		0.00020	
Second Nearest Contract (Sept.1987 - June 1992)				
Sept. 1987 - Dec. 1989	0.00007	1.17**	0.00017	1.13
March 1990 - June 1992	0.00006		0.00015	

Goldfeld-Quandt Test : $F[n1 - K, n2 - K] = S^2_1/S^2_2$
If $F_{calculated} > F_{critical}$ - Reject hypothesis of equal variance between groups.
* Significant at the 1% level ** Significant at 5% level

Serial Autocorrelation

It has been shown that the estimator obtained from Tobit

MLE model remains consistent, even if the disturbances are shown to be autocorrelated. This finding is especially useful because a full MLE that takes account of even a simple type of serial correlation seems computationally intractable. The autocorrelation of the disturbances, ϵ_{jt}, need not to be estimated to compute the Tobit MLE but must estimated to estimate its asymptotic variance-covariance matrix. In our study, autocorrelation of the disturbances was found to be not substantially large. The largest value found when examining the first order autocorrelation of the residuals,e_{jt}, was of 0.285, but with the average value being around 0.10. Although, the data was derived from fifteen-minute interval returns, which we would expect to find large autocorrelation between residuals, the low autocorrelation is due to fact that the data consists of non-continuous days- that is, only Mondays(Fridays) in a twelve day window around expiration are included over the ten year period. Consequently, first order correlation includes correlation for returns that are fifteen minute apart,as well as for returns that are five business days apart. Therefore, first order autocorrelation has absolutely no meaning; as such, examining higher order autocorrelation will provide no useful insight.

D.2. Findings

A Tobit MLE regression is carried out which consists of regressing the absolute deviation of fifteen-minute returns for the expiring contract and the second nearest contract, separately, around the mean return of the fifteen-minute interval j on a series of dummy variables representing the expiration Monday(previous Friday) and various microeconomic announcements. In other words, a Tobit MLE regression is applied to the model[2] mentioned previously. However, Tobit regressions are applied separately to data that includes the whole trading day for Mondays and Fridays,respectively, and for each forty-five minute time span included in the trade day, which consist of three fifteen-minute interval returns for each time span on the Mondays and Fridays in the twelve day window around expiration. For the expiring contract only, the Mondays consist of fifteen minute intervals returns for the first two hours of ten minutes of trade; the reason for this, is that the expiring contract trades for only two hour and ten minutes on the expiration day (7:20-9:30). In a Tobit regression the Chi-Square statistic is used to test the significance of parameter estimates.The critical chi-square statistic for each parameter under the different scenario's examined in this paper is always distributed with the degree of freedom equal to 1. Consequently, the critical chi-square values for the 1%,5% and 10% level of significance are the following: 1% -- 6.63, 5% -- 3.84,and 10% --- 2.71.

Table IX shows regression results based on fifteen minute interval returns for the expiring contract on Mondays included in the twelve day window in each five year subperiod. Results reveal that no matter whether the regression is carried out for data that entails fifteen-minute interval returns for the whole two hour and ten minutes or for each forty-five minute time span, the intercept is found to be significantly different than zero. The intercept represents the volatilty of the fifteen minute interval returns, included in the whole trading day or in each forty-five minute time span, when no announcements have been released for one of the 27 fifteen minute intervals during day, or for one of the three fifteen minute intervals during the the forty-five minute time span, and the Monday in question is not an expiration Monday. In the first five year period, the paremeter estimate for the expiration Monday is positive for the 7:30 - 8:00 time span, but is found to be not significantly different than zero. As such, the volatilty on the expiration Monday in this time span for the given subperiod is larger, but not significantly different than the volatility on Non-expiration Mondays in the same time span . However, in the other two forty-five minute time span included in the two hour and ten minutes trading day the coefficient for the expiration day is negative, but not significantly different than zero. In the second five year period, the expiration day coefficient for the 7:30-8:00 time span is negative and significantly different than zero. As such, the volatility in this time span for the given subperiod is significantly smaller on Expiration Mondays than on Non-expiration Mondays. However, the expiration day parameter estimates are negative for the other two forty-five minute time spans , but not significantly different than zero. Given that the two surveys used by the CME to establish the settlement rate for the expiring contract are carried out within the last 90 minutes of trade, which include both the 8:15-8:45 and 9:00 - 9:30 forty-five minute time spans, it is possible that the survey causes a rise in volatility, but not significantly higher than the volatility present on Non-expiration Mondays for the same time span. As for announcement releases that occur on the Expiring Mondays and Non-expiring Mondays in which the expiring contract is still traded, the coefficients are generally positive but not significantly different than zereo in both subperiods.

Table X.A. and Table X.B. show regression results based on fifteen-minute interval returns for the second nearest contract traded on the Mondays in the twelve day window around the expiration day. In both Table X.A and Table X.B , the intercept is found to be positive and significantly different than zero. In Table X.A, which investigates the first five year subperiod, shows that for the entire six hours and forty minutes the expiration day coefficient is positive and significantly different than zero. As such, the volatility of the second nearest contract on the day the expiring contract expires is higher than on Non-expiring Mondays in the twelve day window around expiration. However, when the day is broken up into forty-five minute time spans, of which each span includes three fifteen-minute interval returns[48], the only time span that shows some degree of positive significance is the coefficient for the 8:15-8:45 time span. This is especially significant since this time span is included in the last 90 minutes of trade when the CME conducts its survey and the public announcement releases that occur in this time span are found to be insignificant. In the second five year subperiod, Table X.B shows that for the entire six hour and forty minutes the expiration day coefficient is found to be negative and significantly different than zero. This negative significance is present in both the 7:30-8:00 and 8:15-8:45 time span. However, for the 9:45-10:15 time span the coefficient is positive,but not significantly different than zero. For the other forty five minutes time spans included during the day, the expiration coefficients are negative but not significantly different than zero. Overall, the volatility of the second nearest contract on the Expiration Mondays in the second five year subperiod is lower than on Non-expiration Mondays, except during the 9:45-10:15 time span,which is the time span that immediately follows the 9:30a.m close for the expiring contract, where volatility rises but not significantly. With respect to announcements released on Mondays, none of the coefficients are found to be significantly different than zero in both subperiods. This is mostly likely due to the fact that their are not many announcement releases that occur on Mondays.

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[48]Prior to November 15th 1985, the 7:30-8:00 time span includes only two fifteen-minute intervals since Eurodollar Futures trading became at 7:30 a.m. instead at 7:20 a.m.

Table XI.A and Table XI.B show regression results based on fifteen-minute interval returns for the expiring contract traded on Fridays included in the twelve day window around the expiration day. In both tables, the intercept is found to positive and significantly different than zero. Table XI.A, which investigates the first five year subperiod, shows that the coefficient estimates for the previous Friday parameter are overall generally positive, but not significantly different than zero. Whereas, Table XI.B, which investigates the second five year period, reveals that for the previous Friday parameter the coefficient is negative and statistically different than zero for the entire day , the 7:30-8:00 and the 12:00-12:30 time span. However, the coefficient is positive for the 11:15-11:45 and 12:45-13:15 time span, but not statistically different than zero. As such,the volatility of the expiring contract in the second subperiod rises near the close on the previous friday before the expiration day, but not significantly higher than the volatility of the other fridays in the twelve day window. Overall, in the second subperiod, the volatility of the expiring contract drops as there is less interest in a contract that is one day away from expiring. With respect to public announcements that occur on fridays in which the expiring contract is traded, results in both tables reveal that the Producer Price Index(PPI) and the Employment Report(EMP) announcement has significant effect on the volatility of Eurodollar futures prices. The coefficients of both these two announcements are found to be positive and very much significantly different than zero in the entire day span. Furthermore, the Employment report is found to be positive and significantly different than zero in the 7:30-8:00 time span, which includes the time of day that the Employment report is released. Even though the PPI and the EMP announcements are released at the same time of day,in our study, these two announcements are in a large part not released on the same Fridays.

Table XII.A and Table XII.B show regression results based on fifteen minute interval returns for the second nearest contract traded on the Fridays in the twelve day window around the expiration day. In the first five year period, Table XII.A, the coefficient for the previous Friday parameter is found to be positive, but not significantly different than zero.However, in the second five year period, Table XII.B, the previous Friday parameter shows no specific pattern and none of the previous Friday coefficients are found to be significantly different than zero. With respect to the microeconomic announcements, the MTD,PPI,EMP,CPI and GNP announcements are found to have coefficients that are positive and significantly different than zero. However, the EMP and PPI announcements seem to have the greatest impact on market price volatility, which is probably due to the fact that a large number of these two announcements were released on the Fridays in the twelve day window over the ten year period and both are frequently used to gauge the direction of short-term interest rates.

Overall,therefore, based on the results provided in the various Tables mentioned in the above paragraphs, the expiration of the nearest contract does not in any way increase significantly the volatility of market prices for the expiring contract or the second nearest contract on both the previous Friday and the Expiration Monday. Consequently,any private information that may be released from the two surveys that are carried out by the CME in order to determine an appropriate settlement price for the expiring Eurodollar contract has no significant impact on the market. However, public macroeconomic announcements, especially the Producer Price Index and the Employment Report figures, cause market price volatility to rise near the time of day that the announcement is released. Ederington and Lee[1993] reveals that although the bulk of the price adjustment for major microeconomic announcements occurs within the first minute , volatility remains substantially higher than normal for roughly fifteen minutes. Therefore, any significant rise in volatility on the previous Fridays or on the Expiration Days would most likely be the result of the release of macroeconomic information, rather than the fact that the CME will shortly call for the final settlement of the nearest Eurodollar futures contract.

5. CONCLUSION

The unique settlement procedure used by the Chicago Mercantile Exchange to settle the Eurodollar futures contract gave rise to the problem of testing the effectiveness of such method, i.e., cash settlement with a settlement index obtained from market participants. Such construction of a settlement index may be subject to distortion and the settlement value may not reflect the true market conditions. This paper examine three parameters associated with Eurodollar futures(trading volume, Three-month LIBOR quotes, and price volatility), to see whether they experience abnormal changes around expiration days. Any abnormal changes could prove to be problematic for hedgers and arbitrageurs as they lift their position near the expiration, or result in some form of opportunity for speculators and spreaders to speculate on.

As the expiration approaches, trading volume of Eurodollar futures increases, reflecting the unwinding of hedged positions and the rolling over maturing contracts. Even with the increased market activity, the survey of LIBOR for settlement does not have much impact on the Eurodollar futures market in terms of daily and intraday price volatility, and the LIBOR quotes obtained through the survey do not systematically differ from the LIBORs quoted on the surrounding days. The evidence presented in this study proves that the settlement method of Eurodollar futures works properly and is not subject to manipulation.

However, if prices adjust rapidly to new information it is possible that the 15 minute interval analysis failed to detect any increase in volatility around the time the CME conducts its survey of LIBOR simply because the market reaction to such an event was short lived. As such, using a 5 minute or a 1 minute interval instead of a 15 minute one, could prove to be a more accurate reflection of price movements during the settlement period. Furthermore, given the fact that it is believed that the variance of futures prices tends to change over time - for example, the variance within a day is said not to be constant- using a model in which the assumption of homoscedasticity is relaxed, would most likely provide more accurate results since such a model would better fit the data. It would be interesting therefore to see if one would find the same results if a model based on conditional heteroscedasticity is used instead.

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TABLES

Table I

Average Relative Volumes and Open Interest of Eurodollar Futures around Expiration Days

Days	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
March 1982 - June 1992, Number of Settlement Days = 42											
RVOL	0.928 (0.233)	0.998 (0.276)	1.102 (0.400)	1.195 (0.394)	1.377 (0.392)	0.979 (0.243)	1.000 (0.284)	0.934 (0.243)	0.923 (0.247)	0.855 (0.346)	0.707 (0.237)
ROI	1.046 (0.050)	1.050 (0.043)	1.052 (0.038)	1.052 (0.034)	1.055 (0.031)	1.056 (0.031)	0.917 (0.032)	0.925 (0.034)	0.932 (0.040)	0.943 (0.048)	0.948 (0.054)
VOL/OI	0.190 (0.078)	0.198 (0.067)	0.221 (0.101)	0.239 (0.098)	0.281 (0.117)	0.197 (0.078)	0.231 (0.090)	0.220 (0.101)	0.217 (0.107)	0.202 (0.116)	0.162 (0.081)
March 1982 - March 1987, N = 21											
RVOL	1.022 (0.195)	1.084 (0.262)	1.096 (0.287)	1.114 (0.287)	1.262 (0.328)	1.078 (0.269)	0.963 (0.267)	0.926 (0.278)	0.956 (0.234)	0.805 (0.272)	0.729 (0.234)
ROI	1.031 (0.063)	1.034 (0.054)	1.040 (0.046)	1.040 (0.040)	1.039 (0.032)	1.039 (0.031)	0.921 (0.039)	0.930 (0.041)	0.941 (0.050)	0.955 (0.060)	0.963 (0.067)
VOL/OI	0.210 (0.067)	0.216 (0.058)	0.230 (0.106)	0.234 (0.106)	0.270 (0.130)	0.221 (0.084)	0.225 (0.094)	0.222 (0.117)	0.234 (0.138)	0.200 (0.126)	0.166 (0.086)
June 1987 - June 1992, N = 21											
RVOL	0.834 (0.235)	0.912 (0.269)	1.109 (0.496)	1.276 (0.471)	1.493 (0.424)	0.881 (0.169)	1.038 (0.302)	0.942 (0.210)	0.889 (0.261)	0.904 (0.409)	0.685 (0.243)
ROI	1.062 (0.023)	1.061 (0.024)	1.063 (0.023)	1.065 (0.024)	1.071 (0.020)	1.072 (0.019)	0.913 (0.022)	0.921 (0.024)	0.922 (0.023)	0.931 (0.028)	0.933 (0.029)
VOL/OI	0.169 (0.084)	0.180 (0.071)	0.213 (0.096)	0.243 (0.091)	0.292 (0.105)	0.174 (0.067)	0.236 (0.089)	0.217 (0.085)	0.200 (0.065)	0.204 (0.107)	0.158 (0.077)

standard deviations are in parentheses

Table II

Average Relative Levels and Percentage Changes of LIBOR around Expiration Days

Days	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
March 1982 - June 1992, Number of Settlement Days = 42											
RLIBOR	0.996 (0.018)	0.996 (0.013)	0.999 (0.014)	1.000 (0.013)	1.003 (0.015)	0.999 (0.014)	0.999 (0.012)	0.997 (0.014)	1.001 (0.012)	1.003 (0.016)	1.006 (0.023)
%change $(L_t-L_{t-1})/L_{t-1}$ X 100	-0.163 (0.171)	0.011 (0.118)	0.242 (0.081)	0.117 (0.106)	0.275 (0.096)	-0.333 (0.158)	0.015 (0.104)	-0.167 (0.110)	0.349 (0.113)	0.201 (0.098)	0.276 (0.169
March 1982 - March 1987, N = 21											
RLIBOR	0.996 (0.022)	0.995 (0.016)	0.996 (0.017)	1.001 (0.016)	1.005 (0.017)	0.999 (0.016)	0.998 (0.014)	0.997 (0.018)	1.002 (0.015)	1.005 (0.020)	1.009 (0.027)
%change $(L_t-L_{t-1})/L_{t-1}$ X 100	0.342 (0.174)	-0.073 (0.151)	0.124 (0.100)	0.482 (0.108)	0.407 (0.112)	-0.537 (0.198)	-0.133 (0.139)	-0.074 (0.102)	0.547 (0.141)	0.273 (0.109)	0.498 (0.161)
June 1987 - June 1992, N = 21											
RLIBOR	0.997 (0.012)	0.998 (0.010)	1.001 (0.010)	0.999 (0.010)	1.000 (0.011)	0.999 (0.013)	1.001 (0.010)	0.998 (0.008)	0.999 (0.007)	1.001 (0.011)	1.002 (0.016)
%change $(L_t-L_{t-1})/L_{t-1}$ X100	-0.668 (0.155)	0.095 (0.074)	0.359 (0.057)	-0.248 (0.091)	0.144 (0.077)	-0.129 (0.105)	0.164 (0.049)	-0.260 (0.119)	0.151 (0.074)	0.129 (0.087)	0.054 (0.179)

Standard deviations are in parentheses.

Table III.A

Tests of Differences in Mean and Variance for Relative Level and Percentage Change of LIBOR on Expiration Mondays vs. Non-Expiration Mondays (in the 12 day window)

	Expiration Mondays (N = 42)	Non-Expiration Mondays (N = 84)	T-statistic[a]	F-statistic[b]
March 1982 - June 1992				
RLIBOR	0.999 (0.014)[c]	1.000 (0.021)	-0.643	2.10*
% change	-0.333 (0.158)	0.056 (0.170)	-1.237	1.16
March 1982 - March 1987 (N = 21,42)				
RLIBOR	0.999 (0.016)	1.002 (0.025)	-0.696	2.56*
%change	-0.537 (0.198)	0.419 (0.166)	-2.02*	1.44
June 1987 - June 1992 (N = 21,42)				
RLIBOR	0.999 (0.013)	0.999 (0.014)	-0.103	1.27
% change	-0.129 (0.106)	-0.307 (0.169)	0.510	2.57*

[a] This t-test tests the hypothesis that the true mean of the two groups are the same. The underlying assumption is that the variables are normally and independently distributed within each group.If variances are not equal between groups, the t-statistics is adjusted to take this into consideration. The adjustment is done on the degree of freedom figure by the Proc Ttest procedure available on SAS. The t-statistics shown examine whether the means of the two groups are significantly different.

[b] This F-test tests the hypothesis that the variance of the groups are the same. The F-statistics shown examine whether the variances of the two groups are significantly different.

[c] Standard deviations are in parentheses.

* Significant at the 5% level

Table III.B

Tests of Differences in Mean and Variance for Relative Level and Percentage Change of LIBOR on Expiration Fridays(Fridays before the Expiration) vs. Non-Expiration Fridays(in the 12 day window)

	Expiration Fridays (N = 42)	Non-Expiration Fridays (N = 84)	T-statistic[a]	F-statistic[b]
March 1982 - June 1992				
RLIBOR	1.002 (0.015)[c]	1.000 (0.021)	0.745	2.02*
% change	0.275 (0.096)	0.122 (0.099)	0.821	1.08
March 1982 - March 1987 (N = 21,42)				
RLIBOR	1.005 (0.017)	0.999 (0.024)	0.998	1.90
%change	0.407 (0.112)	0.082 (0.102)	1.15	1.22
June 1987 - June 1992 (N = 21,42)				
RLIBOR	1.000 (0.011)	1.001 (0.017)	-0.338	2.37*
% change	0.144 (0.077)	0.162 (0.099)	-0.073	1.65

[a] This t-test tests the hypothesis that the true mean of the two groups are the same. The underlying assumption is that the variables are normally and independently distributed within each group. If variances are not equal between groups, the t- statistics is adjusted to take this into consideration. The adjustment is done on the degree of freedom figure by the Proc Ttest procedure available on SAS. The t-statistics shown examine whether the means of the two groups are significantly different.

[b] This F-test tests the hypothesis that the variance of the groups are the same. The F-statistics shown examine whether the variances of the two groups are significantly different.

[c] Standard deviations are in parentheses.

* Significant at the 5% level

Table IV

Mean Reversals of Percentage Change in Three-month LIBOR around Expiration Days

Days	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
March 1982 - June 1992, Number of Settlement Days = 42											
Type 0 Reversal	-0.109 (0.113)	-0.229 (0.082)	0.119 (0.106)	-0.075 (0.100)	0.221 (0.160)	0.014 (0.104)	-0.253 (0.108)	0.063 (0.118)	-0.075 (0.100)	0.113 (0.172)	-0.020 (0.097)
Type 1 Reversal	0.337 (0.075)	0.172 (0.042)	0.490 (0.071)	0.294 (0.060)	0.774 (0.095)	0.319 (0.072)	0.233 (0.060)	0.435 (0.078)	0.342 (0.055)	0.658 (0.110)	0.317 (0.060)
Type 2 Reversal	0.460 (0.092)	0.305 (0.062)	0.358 (0.063)	0.347 (0.059)	0.339 (0.062)	0.685 (0.101)	0.241 (0.069)	0.490 (0.078)	0.304 (0.062)	0.426 (0.052)	0.652 (0.127)
March 1982 - March 1987, N = 21											
Type 0 Reversal	-0.010 (0.145)	-0.159 (0.099)	-0.011 (0.119)	-0.259 (0.116)	0.491 (0.200)	-0.050 (0.140)	-0.419 (0.093)	0.042 (0.151)	-0.004 (0.113)	-0.324 (0.165)	-0.006 (0.110)
Type 1 Reversal	0.538 (0.096)	0.281 (0.055)	0.452 (0.073)	0.281 (0.068)	1.09 (0.113)	0.432 (0.095)	0.173 (0.038)	0.603 (0.093)	0.459 (0.064)	0.440 (0.056)	0.424 (0.053)
Type 2 Reversal	0.418 (0.076)	0.419 (0.076)	0.425 (0.072)	0.243 (0.059)	0.486 (0.078)	0.827 (0.129)	0.388 (0.094)	0.594 (0.073)	0.462 (0.080)	0.424 (0.054)	0.805 (0.126)
June 1987 - June 1992, N = 21											
Type 0 Reversal	-0.208 (0.071)	-0.300 (0.061)	0.248 (0.091)	0.109 (0.077)	-0.049 (0.106)	0.078 (0.051)	-0.087 (0.121)	0.084 (0.075)	-0.146 (0.087)	0.551 (0.171)	-0.035 (0.085)
Type 1 Reversal	0.136 (0.036)	0.063 (0.020)	0.527 (0.070)	0.307 (0.052)	0.456 (0.059)	0.206 (0.035)	0.294 (0.076)	0.266 (0.059)	0.224 (0.043)	0.876 (0.143)	0.210 (0.065)
Type 2 Reversal	0.502 (0.107)	0.191 (0.042)	0.291 (0.052)	0.450 (0.060)	0.191 (0.036)	0.543 (0.063)	0.094 (0.022)	0.386 (0.083)	0.147 (0.031)	0.408 (0.051)	0.499 (0.130)

Standard deviations are in parentheses

Table V.A

Tests of Differences in Mean and Variance for Reversal of the Percentage Change in LIBOR on Expiration Mondays vs.Non-Expiration Mondays (in the 12 day window)

	Expiration Mondays (N = 42)	Non-Expiration Mondays (N = 84)	T-statistic[a]	F-statistic[b]
March 1982 - June 1992				
REVO	0.014 (0.104)[c]	-0.065 (0.105)	0.398	1.01
REV1	0.319 (0.072)	0.327 (0.067)	-0.06	1.15
REV2	0.685 (0.101)	0.556 (0.111)	0.632	1.21
March 1982 - March 1987 (N = 21,42)				
REVO	-0.050 (0.140)	-0.007 (0.127)	-0.121	1.21
REV1	0.432 (0.095)	0.481 (0.077)	-0.221	1.53
REV2	0.827 (0.129)	0.612 (0.105)	0.712	1.51
June 1987 - June 1992 (N = 21,42)				
REVO	0.078 (0.051)	-0.122 (0.078)	1.22	2.34*
REV1	0.206 (0.035)	0.173 (0.052)	0.295	2.15
REV2	0.542 (0.063)	0.500 (0.118)	0.184	3.51**

[a] This t-test tests the hypothesis that the true mean of the two groups are the same. The underlying assumption is that the variables are normally and independently distributed within each group. If variances are not equal between groups, the t- statistics is adjusted to take this into consideration. The adjustment is done on the degree of freedom figure by the Proc Ttest procedure available on SAS.The t-statistics shown examine whether the means of the two groups are significantly different.
[b] This F-test tests the hypothesis that the variance of the groups are the same. The F-statistics shown examine whether the variance of the two groups are significantly different.
[c] Standard deviations are in parantheses.
* Significant at the 5% level
** Significant at the 1% level

Table V.B

Tests of Differences in Mean and Variance for Reversal of the Percentage Change in LIBOR on Expiration Fridays(Fridays before Expiration) vs. Non-Expiration Fridays (in the 12 day window)

	Expiration Fridays (N = 42)	Non-Expiration Fridays (N = 84)	T-statistic[a]	F-statistic[b]
March 1982 - June 1992				
REVO	0.221	-0.015	0.741	1.15
	(0.160)[c]	(0.172)		
REV1	0.774	0.610	0.887	1.10
	(0.094)	(0.099)		
REV2	0.339	0.371	-0.312	1.44
	(0.062)	(0.051)		
March 1982 -March 1987 (N = 21,42)				
REVO	0.492	-0.155	1.329	1.34
	(0.200)	(0.173)		
REV1	1.09	0.578	2.00*	1.65
	(0.113)	(0.088)		
REV2	0.486	0.358	0.674	2.14*
	(0.078)	(0.054)		
June 1987 - June 1992 (N = 21,42)				
REVO	-0.050	0.125	-0.494	2.64*
	(0.106)	(0.173)		
REV1	0.456	0.641	-0.866	3.56**
	(0.058)	(0.111)		
REV2	0.191	0.384	-1.577	1.97
	(0.036)	(0.050)		

[a] This t-test tests the hypothesis that the true mean of the two groups are the same. The underlying assumption is that the variables are normally and independently distributed within each group. If variances are not equal between groups, the t- statistics is adjusted to take this into consideration. The adjustment is done on the degree of freedom figure by the Proc Ttest procedure available on SAS.The t-statistics shown examine whether the means of the two groups are significantly different.

[b] This F-test tests the hypothesis that the variance of the groups are the same. The F-statistics shown examine whether the variance of the two groups are significantly different.

[c] Standard deviations are in parentheses.
* Significant at the 5% level
** Significant at the 1% level

Table VI

Average Daily Volatility (X 10^{-2}) of Eurodollar Futures Prices around Expiration Days for the First Four Nearest Contracts (15 minute intervals for the six hours and forty minutes on each trading day and for two hours and ten minutes for the expiring contract on the expiration day)

Days	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
June 1982 - June 1992, Number of Settlement Days = 41											
First Nearest Contract	0.0007 (0.0017)	0.0005 (0.0009)	0.0006 (0.0011)	0.0004 (0.0006)	0.0008 (0.0012)	0.0003 (0.0010)					
Second Nearest Contract	0.0014 (0.0024)	0.0011 (0.0023)	0.0014 (0.0020)	0.0012 (0.0017)	0.0025 (0.0038)	0.0019 (0.0031)	0.0010 (0.0009)	0.0019 (0.0059)	0.0010 (0.0011)	0.0017 (0.0028)	0.0014 (0.0043)
Third Nearest Contract	0.0013 (0.0022)	0.0011 (0.0019)	0.0012 (0.0017)	0.0012 (0.0016)	0.0027 (0.0044)	0.0015 (0.0028)	0.0011 (0.0012)	0.0020 (0.0050)	0.0010 (0.0012)	0.0016 (0.0024)	0.0011 (0.0027)
Fourth Nearest Contract	0.0013 (0.0022)	0.0010 (0.0016)	0.0011 (0.0015)	0.0011 (0.0014)	0.0028 (0.0049)	0.0015 (0.0025)	0.0011 (0.0013)	0.0021 (0.0048)	0.0009 (0.0012)	0.0014 (0.0016)	0.0008 (0.0014)
June 1982 - June 1987, N = 21											
First Nearest Contract	0.0012 (0.0023)	0.0009 (0.0013)	0.0008 (0.0012)	0.0005 (0.0006)	0.0011 (0.0016)	0.0006 (0.0014)					
Second Nearest Contract	0.0024 (0.0031)	0.0017 (0.0031)	0.0021 (0.0025)	0.0014 (0.0014)	0.0035 (0.0049)	0.0034 (0.0052)	0.0009 (0.0007)	0.0030 (0.0082)	0.0015 (0.0014)	0.0015 (0.0019)	0.0023 (0.0059)
Third Nearest Contract	0.0022 (0.0029)	0.0013 (0.0022)	0.0018 (0.0021)	0.0014 (0.0017)	0.0039 (0.0057)	0.0027 (0.0036)	0.0011 (0.0010)	0.0032 (0.0067)	0.0015 (0.0014)	0.0012 (0.0011)	0.0016 (0.0038)
Fourth Nearest Contract	0.0022 (0.0027)	0.0011 (0.0015)	0.0015 (0.0018)	0.0013 (0.0016)	0.0040 (0.0065)	0.0027 (0.0031)	0.0011 (0.0012)	0.0033 (0.0066)	0.0013 (0.0015)	0.0012 (0.0011)	0.0011 (0.0019)
Sept 1987 - June 1990, N = 20											
First Nearest Contract	0.0002 (0.0003)	0.0002 (0.0002)	0.0004 (0.0008)	0.0004 (0.0006)	0.0005 (0.0005)	0.00004 (0.00001)					
Second Nearest Contract	0.0004 (0.0007)	0.0006 (0.0008)	0.0006 (0.0010)	0.0011 (0.0020)	0.0014 (0.0016)	0.0003 (0.0003)	0.0010 (0.0011)	0.0007 (0.0008)	0.0004 (0.0004)	0.0020 (0.0035)	0.0004 (0.0004)
Third Nearest Contract	0.0005 (0.0006)	0.0009 (0.0014)	0.0007 (0.0009)	0.0010 (0.0015)	0.0016 (0.0020)	0.0003 (0.0004)	0.0011 (0.0014)	0.0007 (0.0008)	0.0004 (0.0004)	0.0021 (0.0033)	0.0004 (0.0004)
Fourth Nearest Contract	0.0004 (0.0005)	0.0009 (0.0017)	0.0007 (0.0010)	0.0009 (0.0011)	0.0015 (0.0018)	0.0003 (0.0003)	0.0011 (0.0015)	0.0007 (0.0007)	0.0004 (0.0004)	0.0016 (0.0021)	0.0005 (0.0004)

Standard deviations are in parentheses.

Table VII

Average Daily Volatility (X 10^{-2}) of Eurodollar Futures Prices around Expiration Days for the First Four Nearest Contracts(7½ minute intervals for the first two hours and ten minutes on each trading day)

Days	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
June 1982 - June 1992, Number of Settlement Days = 41											
First Nearest Contract	0.0003 (0.0004)	0.0002 (0.0003)	0.0003 (0.0005)	0.0002 (0.0003)	0.0005 (0.0006)	0.0003 (0.0011)					
Second Nearest Contract	0.0004 (0.0007)	0.0003 (0.0003)	0.0006 (0.0010)	0.0007 (0.0008)	0.0015 (0.0017)	0.0007 (0.0014)	0.0007 (0.0008)	0.0008 (0.0021)	0.0004 (0.0005)	0.0013 (0.0042)	0.0005 (0.0011)
Third Nearest Contract	0.0004 (0.0006)	0.0004 (0.0005)	0.0005 (0.0006)	0.0006 (0.0006)	0.0016 (0.0019)	0.0007 (0.0016)	0.0008 (0.0012)	0.0010 (0.0030)	0.0005 (0.0007)	0.0014 (0.0041)	0.0005 (0.0009)
Fourth Nearest Contract	0.0005 (0.0011)	0.0004 (0.0006)	0.0005 (0.0007)	0.0006 (0.0006)	0.0017 (0.0021)	0.0005 (0.0008)	0.0007 (0.0011)	0.0010 (0.0033)	0.0006 (0.0009)	0.0311 (0.0027)	0.0004 (0.0005)
June 1982 - June 1987, N = 21											
First Nearest Contract	0.0004 (0.0005)	0.0003 (0.0004)	0.0004 (0.0007)	0.0003 (0.0003)	0.0006 (0.0006)	0.0006 (0.0015)					
Second Nearest Contract	0.0006 (0.0009)	0.0004 (0.0004)	0.0009 (0.0013)	0.0007 (0.0007)	0.0017 (0.0021)	0.0012 (0.0018)	0.0006 (0.0006)	0.0012 (0.0029)	0.0006 (0.0006)	0.0006 (0.0005)	0.0007 (0.0015)
Third Nearest Contract	0.0005 (0.0008)	0.0004 (0.0005)	0.0007 (0.0007)	0.0006 (0.0004)	0.0019 (0.0023)	0.0013 (0.0021)	0.0006 (0.0005)	0.0015 (0.0042)	0.0007 (0.0008)	0.0008 (0.0008)	0.0006 (0.0012)
Fourth Nearest Contract	0.0008 (0.0015)	0.0004 (0.0006)	0.0007 (0.0009)	0.0005 (0.0005)	0.0020 (0.0026)	0.0010 (0.0010)	0.0005 (0.0007)	0.0016 (0.0045)	0.0008 (0.0012)	0.0008 (0.0010)	0.0004 (0.0006)
Sept 1987 - June 1990, N = 20											
First Nearest Contract	0.00009 (0.00009)	0.0001 (0.0001)	0.0002 (0.0003)	0.0002 (0.0003)	0.0004 (0.0005)	0.00004 (0.00001)					
Second Nearest Contract	0.0002 (0.0003)	0.0002 (0.0003)	0.0003 (0.0005)	0.0006 (0.0008)	0.0012 (0.0014)	0.0002 (0.0001)	0.0007 (0.0010)	0.0004 (0.0006)	0.0003 (0.0003)	0.0021 (0.0059)	0.0002 (0.0002)
Third Nearest Contract	0.0002 (0.0002)	0.0003 (0.0005)	0.0003 (0.0004)	0.0006 (0.0008)	0.0014 (0.0015)	0.0001 (0.0001)	0.0009 (0.0016)	0.0004 (0.0006)	0.0003 (0.0003)	0.0021 (0.0059)	0.0003 (0.0003)
Fourth Nearest Contract	0.0001 (0.0001)	0.0003 (0.0006)	0.0003 (0.0004)	0.0006 (0.0007)	0.0014 (0.0015)	0.00009 (0.00008)	0.0008 (0.0015)	0.0004 (0.0005)	0.0004 (0.0005)	0.0015 (0.0037)	0.0003 (0.0002)

Standard deviations are in parentheses.

Table VIII.A

Tests of Differences in Daily Mean Volatilities(X 10^{-2}) of Eurodollar Futures Prices on Expiration Mondays vs. Non-expiration Mondays in twelve day window.(for the first two hours and ten minutes)

	Expiration Mondays (N = 41)	Non-Expiration Mondays (N = 82)	DF	T-statistic[a]	DF	F-statistic[b]
June 1982 - June 1992						
First Contract (N= 41,41)	0.00030 (0.0011)[c]	0.00026 (0.0004)	49	0.255	40,40	8.71**
Second Contract	0.00068 (0.0014)	0.00043 (0.0009)	58	1.032	40,81	2.32**
Third Contract	0.00073 (0.0016)	0.00041 (0.0008)	49	1.202	40,81	4.50**
Fourth Contract	0.00053 (0.0008)	0.00043 (0.0008)	121	0.652	40.81	1.02
June 1982 - June 1987 (N = 21,42)						
First Contract (N = 21,21)	0.00056 (0.0015)	0.00042 (0.00045)	24	0.417	20,20	10.68**
Second Contract	0.00119 (0.0018)	0.00065 (0.0013)	29	1.238	20,41	2.22*
Third Contract	0.00130 (0.0021)	0.00057 (0.0010)	25	1.496	20,41	4.42**
Fourth Contract	0.00095 (0.0010)	0.00062 (0.0011)	61	1.154	41,20	1.22
Sept. 1987 - June 1992 (N = 20,40)						
First Contract (N = 20,20)	0.000037 (0.000012)	0.000091 (0.000086)	20	-2.79**	19,19	47.91**
Second Contract	0.00015 (0.00018)	0.00021 (0.00028)	58	-0.918	39,19	2.30
Third Contract	0.00012 (0.00010)	0.00023 (0.00027)	55	-2.30*	39,19	7.46**
Fourth Contract	0.000089 (0.000078)	0.00022 (0.00022)	55	-3.51**	39,19	7.66**

[a] This t-test tests the hypothesis that the true mean of the two groups are the same. The underlying assumption is that the variables are normally and independently distributed within each group. If variances are not equal between groups, the t-statistics is adjusted to take this into consideration. The adjustment is done on the degree of freedom figure by the Proc Ttest procedure available on SAS.
The t-statistics shown examine whether the means of the two groups are significantly different.

[b] This F-test tests the hypothesis that the variance of the groups are the same. The F-statistics shown examine whether the variance of the two groups are significantly different.

[c] Standard deviations are in parentheses.

* Significant at the 5% level
** Significant at the 1% level
DF = Degree of Freedom

Table VIII.B

Tests of Differences in Daily Mean Volatilities(X 10^{-2}) of Eurodollar Futures Prices on Expiration Fridays (Fridays before the Expiration) vs. Non-expiration Fridays in twelve day window(for the entire six hours and forty minutes)

	Expiration Fridays (N = 41)	Non-Expiration Fridays (N = 82)	DF	T-statistic[a]	DF	F-statistic[b]
June 1982 - June 1992						
First Contract (N= 41,41)	0.00079 (0.0012)[c]	0.00114 (0.0022)	63	-0.871	40,40	3.18**
Second Contract	0.00248 (0.0038)	0.00207 (0.0031)	121	0.650	40,81	1.56
Third Contract	0.00274 (0.0044)	0.00179 (0.0023)	51	1.278	40,81	3.72**
Fourth Contract	0.00277 (0.00493)	0.00155 (0.00183)	47	1.533	40,81	7.23**
June 1982 - June 1987 (N = 21,42)						
First Contract (N = 21,21)	0.00108 (0.0016)	0.00136 (0.0029)	31	-0.384	20,20	3.32**
Second Contract	0.00351 (0.00495)	0.00221 (0.00336)	29	1.089	20,41	2.17*
Third Contract	0.00387 (0.0057)	0.00171 (0.0021)	23	1.661	20,41	7.35**
Fourth Contract	0.00400 (0.00651)	0.00150 (0.00197)	22	1.718	20,41	10.91**
Sept. 1987 - June 1992 (N = 20,40)						
First Contract (N = 20,20)	0.00048 (0.00055)	0.00090 (0.0010)	29	-1.569	19,19	3.55**
Second Contract	0.00140 (0.0016)	0.00192 (0.0028)	56	-0.910	39,19	2.88*
Third Contract	0.00156 (0.0020)	0.00189 (0.0025)	58	-0.539	39,19	1.56
Fourth Contract	0.00148 (0.00176)	0.00159 (0.00170)	58	-0.254	19,39	1.07

[a] This t-test tests the hypothesis that the true mean of the two groups are the same. The underlying assumption is that the variables are normally and independently distributed within each group. If variances are not equal between groups, the t- statistics is adjusted to take this into consideration. The adjustment is done on the degree of freedom figure by the Proc Ttest procedure available on SAS.The t-statistics shown examine whether the means of the two groups are significantly different.

[b] This F-test tests the hypothesis that the variance of the groups are the same. The F-statistics shown examine whether the variance of the two groups are significantly different.

[c] standard deviations are in parentheses.

* Significant at the 5% level
** Significant at the 1% level
DF = Degree of freedom

Table IX

Regression Results of Intraday volatility*(X 10^{-2}) of Expiring Eurodollar Futures contract based on 15 minute interval returns of exprireing and non-expiring Mondays in the twelve day window around expiration.

$$*\,|R_{jt}-\overline{R_j}| = a_{oj} + a_{1j}D_{1jt} + \sum_{k=2}^{K} a_{kj}D_{kjt} + e_{jt} \quad [2]$$

Where D_{1jt} = 1 if the Monday t(in a twelve day window around expiration) is an Expiration Monday in the case of the Monday analysis, or if the Friday t(in a twelve day window around expiration) is the previous Friday in the case of the Friday analysis. D_{1jt} = 0 if day t is neither the Expiration Monday, or nor the previous Friday. D_{kjt} = 1 if announcement k is made on the Monday t, or the Friday t, at the 15 minute interval j. D_{kjt} = 0 otherwise. The 15 minute intreval return, Rjt, is equal to $\ln(P_{jt}/P_{jt-1})$. Regression is carried out in a Tobit setting.

	Intercept	Chi-Square	Expiration Day	Chi-Square	CU	Chi-square	FI	Chi-square	MTD	Chi-Square	CPI	Chi-square	IP	Chi-square	D-W	R-square
June 1982 - June 1987																
7:30 - 9:30 (N = 350)	0.0126 (0.0011)	139.5**	-0.0017 (0.0015)	1.21	-0.0041 (0.005)	0.63	0.0001 (0.0071)	0.0002	0.0162 (0.01)	2.60	------	------	-0.0099 (0.0141)	0.49	1.70	0.015
7:30 - 8:00 (n=98)	0.0157 (0.0027)	34.88**	0.0003 (0.0038)	0.006	------	------	------	------	0.0111 (0.013)	0.684	------	------	------	------	1.89	0.007
8:15 - 8:45 (n=126)	0.0130 (0.0017)	57.64**	-0.0032 (0.0025)	1.65	-0.0029 (0.005)	0.32	------	------	------	------	------	------	-0.0088 (0.014)	0.411	1.69	0.024
9:00 - 9:30 (n=126)	0.0097 (0.0011)	79.26**	-0.0019 (0.0016)	1.44	------	------	0.0031 (0.0045)	0.483	------	------	------	------	------	------	1.77	0.013
Sept 1987 - June 1992																
7:30 - 9:30 (N = 360)	0.0082 (0.0005)	262.8**	-0.00184 (0.0007)	6.60**	------	------	0.0009 (0.0048)	0.03	------	------	0.0049 (0.0068)	0.52	-0.0047 (0.0068)	0.48	1.72	0.021
7:30 - 8:00 (n=120)	0.0093 (0.0010)	89.17**	-0.0032 (0.0014)	5.22*	------	------	------	------	------	------	0.0051 (0.0077)	0.44	------	------	1.60	0.043
8:15 - 8:45 (n= 120)	0.0084 (0.0008)	109.59**	-0.0010 (0.0011)	0.857	------	------	------	------	------	------	------	------	-0.0057 (0.0063)	0.835	2.10	0.015
9:00 - 9:30 (n= 120)	0.0068 (0.0008)	73.61**	-0.0013 (0.0011)	1.28	------	------	0.0001 (0.0044)	0.0004	------	------	------	------	------	------	1.55	0.011

Standard Error in Parentheses

* Significant at 5% level ** Significant at 1% level

Table X.A

Regression results of Intraday volatility(X 10^{-2}) for Second Nearest Eurodollar Futures Contract based on 15 minute interval returns of expriring and non-expiring Mondays in a twelve day window around expiration.

(June 1982 - June 1987)

	Intercept	Chi-Sqr	Expiration Day	Chi-Sqr	CU	Chi-Sqr	FI	Chi-Sqr	MTD	Chi-Sqr	CPI	Chi Sqr	IP	Chi-Sqr	D-W	R-square
7:30 - 14:00 (N= 1659)	0.0149 (0.0005)	766.4**	0.0024 (0.0009)	6.64**	-0.0017 (0.0064)	0.07	-0.0089 (0.009)	1.00	0.021 (0.013)	2.76!	---	---	-0.0076 (0.018)	0.18	1.57	0.006
7:30 - 8:00 (n=147)	0.0198 (0.0022)	83.1**	0.0009 (0.0038)	0.06	-------	-------	-------	-------	0.017 (0.016)	1.26	---	---	-------	-------	1.66	0.01
8:15 - 8:45 (n = 189)	0.0159 (0.0018)	77.07**	0.0057 (0.0033)	2.95!	-0.0059 (0.0077)	0.60	-------	-------	-------	-------	---	---	-0.012 (0.021)	0.33	2.08	0.016
9:00 - 9:30	0.0127 (0.0013)	96.88**	0.0009 (0.0023)	0.183	-------	-------	-0.0054 (0.0075)	0.515	-------	-------	---	---	-------	-------	1.45	0.003
9:45 - 10:15	0.0104 (0.0008)	159.5**	0.0011 (0.0014)	0.50	-------	-------	-------	-------	-------	-------	---	---	-------	-------	1.79	0.003
10:30 - 11:00	0.0143 (0.0017)	68.49**	0.0047 (0.0033)	2.53	-------	-------	-------	-------	-------	-------	---	---	-------	-------	1.90	0.013
11:15 - 11:45	0.0135 (0.0014)	95.77**	0.0023 (0.0024)	0.95	-------	-------	-------	-------	-------	-------	---	---	-------	-------	1.60	0.005
12:00 - 12:30	0.0146 (0.0014)	102.32**	0.0006 (0.0025)	0.06	-------	-------	-------	-------	-------	-------	---	---	-------	-------	1.47	0.0
12:45- 13:15	0.0165 (0.0019)	77.98**	0.0011 (0.0032)	0.12	-------	-------	-------	-------	-------	-------	---	---	-------	-------	1.79	0.002
13:30- 14:00	0.0174 (0.0017)	108.5**	0.0043 (0.0029)	2.18	-------	-------	-------	-------	-------	-------	---	---	-------	-------	1.49	0.011

Standard Error in Parentheses

! = Significant at the 10% level
* = Significant at the 5% level
** = Significant at the 1% level

Table X.B

Regression Results of Intraday volatility(X 10^{-2}) of Second Nearest Eurodollar Futures Contract based on 15 minute interval returns of expriring and non-expiring Mondays in a twelve day window around expiration.

(Sept. 1987 - June 1992)

	Intercept	Chi-Sqr	Expiration Day	Chi-Sqr	CU	Chi-Sqr	FI	Chi-Sqr	MTD	Chi-Sqr	CPI	Chi-Sqr	IP	Chi-Sqr	D-W	R-square
7:30 - 14:00 (N=1620)	0.0094 (0.0002)	1605.8**	-0.0012 (0.0004)	8.22**	---	---	-0.0058 (0.0054)	1.14	-----	----	0.013 (0.008)	2.71!	0.0006 (0.008)	0.01	1.74	0.008
7:30 - 8:00 (n=180)	0.0112 (0.0008)	200.8**	-0.0025 (0.0014)	3.28!	---	----	-------	-----	-----	-----	0.0122 (0.009)	1.92	------	----	1.91	0.026
8:15 - 8:45	0.0103 (0.0007)	228.8**	-0.0027 (0.0012)	5.07*	---	----	-------	------	-----	-----	------	----	0.0012 (0.008)	0.02	1.82	0.028
9:00 - 9:30	0.0093 (0.0007)	160.2**	-0.0012 (0.0013)	0.907	---	----	-0.0056 (0.0058)	0.95	-----	-----	------	----	------	----	1.55	0.012
9:45 - 10:15	0.0077 (0.0006)	147.9**	0.00012 (0.0011)	0.01	---	----	-------	-----	-----	-----	------	----	-------	----	1.80	0.000
10:30 - 11:00	0.0084 (0.0006)	196.2**	-0.0002 (0.001)	0.03	---	----	-------	-----	-----	-----	------	----	-------	----	1.57	0.000
11:15 - 11:45	0.0089 (0.0006)	209.9**	-0.0007 (0.0011)	0.42	---	----	-------	-----	-----	-----	------	----	-------	----	2.15	0.002
12:00 - 12:30	0.0081 (0.0006)	174.7**	-0.0009 (0.0011)	0.75	---	----	-------	-----	-----	-----	-------	----	-------	----	1.90	0.004
12:45 - 13:15	0.0102 (0.0007)	222.4**	-0.0019 (0.0012)	2.59	---	----	-------	------	-----	-----	-------	----	-------	----	1.82	0.017
13:30 - 14:00	0.0102 (0.0008)	140.2**	-0.0005 (0.0015)	0.12	---	----	-------	------	-----	-----	-------	----	-------	----	1.53	0.001

Standard Error in Parentheses

! = Significant at the 10% level
* = Significant at the 5% level
** = Significant at the 1% level

Table XI.A

Regression Results of Intraday volatility(X 10^{-2}) of Expiring Eurodollar Futures Contract based on 15 minute interval returns of previous and non-expiration Fridays in a twelve day window around expiration.

(June 1982 - June 1987)

	Inter-cept	Chi-Sqr	Previous Friday	Chi Sqr	CU	Chi Sqr	FI	Chi Sqr	MTD	Chi Sqr	CPI	Chi Sqr	IP	Chi Sqr	PPI	Chi Sqr	EMP	Chi Sqr	D-W	R-Sqr
7:30 - 14:00 (N=1106)	0.0105 (0.0005)	371.8**	0.0012 (0.0008)	2.21	-0.0045 (0.013)	0.13	0.0013 (0.0052)	0.06	0.021 (0.013)	2.60	---	---	0.0007 (0.005)	0.02	0.0127 (0.0031)	16.85**	0.0288 (0.0031)	85.17**	1.68	0.090
7:30 - 8:00 (n=98)	0.0151 (0.0037)	16.6**	0.0052 (0.0051)	1.03	------	---	-------	-----	0.021 (0.022)	0.92	---	---	------	----	0.0043 (0.0062)	0.50	0.0242 (0.0063)	14.68**	1.64	0.143
8:15 - 8:45 (n=126)	0.0124 (0.0016)	59.3**	0.0018 (0.0024)	0.61	-0.0071 (0.013)	0.30	------	----	-----	----	---	---	-0.0032 (0.005)	0.39	-------	------	-------	-------	2.16	0.008
9:00 - 9:30	0.0104 (0.0013)	60.3**	0.0011 (0.0019)	0.31	------	----	0.0015 (0.0046)	0.11	-----	----	---	---	-----	---	------	------	-------	-------	1.50	0.004
9:45 - 10:15	0.0094 (0.0012)	66.9**	-0.0008 (0.0016)	0.25	------	----	-------	----	-----	----	---	---	-----	---	------	------	-------	-------	1.70	0.002
10:30 - 11:00	0.0107 (0.0016)	46.5**	-0.0009 (0.0022)	0.16	------	----	-------	----	-----	----	---	---	-----	---	------	------	-------	-------	1.88	0.001
11:15 - 11:45	0.0098 (0.0011)	82.5**	0.0008 (0.0015)	0.28	------	----	-------	----	-----	----	---	---	-----	---	------	------	-------	-------	1.38	0.002
12:00 - 12:30	0.0077 (0.0013)	37.7**	0.0014 (0.0018)	0.64	------	----	-------	----	-----	----	---	---	-----	---	------	------	-------	-------	1.53	0.005
12:45- 13:15	0.0114 (0.0016)	51.8**	0.0011 (0.0022)	0.25	------	----	-------	----	-----	----	---	---	-----	---	------	------	-------	-------	1.43	0.002
13:30 - 14:00	0.0102 (0.0016)	39.0**	0.0027 (0.0023)	1.37	------	----	-------	----	-----	----	---	---	-----	---	------	------	-------	-------	1.51	0.011

Standard Error in Parentheses

! = Significant at the 10% level
* = Significant at the 5% level
** = Significant at the 1% level

Table XI.B

Regression Results of Intraday volatility(X 10^{-2}) of Expiring Eurodollar Futures Contract based on 15 minute interval returns of previous and non-expiration Fridays in a twelve day window around expiration.

(Sept. 1987 - June 1992)

	Inter-cept	Chi-Sqr	Previous Friday	Chi Sqr	CU	Chi Sqr	FI	Chi Sqr	MTD	Chi Sqr	CPI	Chi Sqr	IP	Chi Sqr	PPI	Chi Sqr	EMP	Chi Sqr	D-W	R-Sqr
7:30 - 14:00 (N=1080	0.0098 (0.0005)	425.1**	-0.0019 (0.0007)	7.82**	0.0045 (0.007)	0.35	-0.0014 (0.011)	0.02	0.032 (0.006)	28.6**	0.0021 (0.005)	0.22	0.0092 (0.009)	1.07	0.0063 (0.0039)	2.64!	0.0426 (0.0031)	193.4**	1.73	0.194
7:30 - 8:00 (n=120)	0.0241 (0.0032)	55.1**	-0.0089 (0.0046)	3.71!	------	----	--------	----	0.030 (0.012)	6.0*	-0.0046 (0.010)	0.22	------	----	-0.0003 (0.0085)	0.001	0.0285 (0.0070)	16.74**	2.05	0.223
8:15 - 8:45	0.0095 (0.0012)	67.4**	-0.0016 (0.0017)	0.84	0.0045 (0.006)	0.48	-------	----	-----	-----	------	---	0.0092 (0.007)	1.57	-------	-----	--------	-------	2.04	0.096
9:00 - 9:30	0.0091 (0.0009)	100.6**	-0.0011 (0.0013)	0.75	-------	----	-0.00076 (0.0071)	0.01	------	-----	------	---	------	----	------	-----	--------	-------	1.65	0.006
9:45 - 10:15	0.0080 (0.0008)	102.7**	-0.0016 (0.0011)	2.00	-------	----	--------	----	-------	-----	-------	---	------	----	------	-----	--------	-------	2.05	0.016
10:30 - 11:00	0.0101 (0.0013)	59.8**	-0.0012 (0.0018)	0.43	-------	----	--------	----	-------	-----	-------	---	------	----	------	-----	--------	-------	1.75	0.004
11:15 - 11:45	0.0063 (0.0007)	75.9**	0.0001 (0.0010)	0.02	-------	----	--------	----	-------	-----	-------	---	------	----	------	-----	--------	-------	1.95	0.000
12:00 - 12:30	0.0083 (0.0009)	77.5**	-0.0027 (0.0013)	4.17*	-------	----	--------	----	-------	-----	-------	---	------	----	------	-----	--------	-------	1.53	0.034
12:45 - 13:15	0.0068 (0.0009)	52.2**	0.0006 (0.0013)	0.19	-------	----	--------	----	-------	-----	-------	---	------	----	-------	-----	--------	-------	1.83	0.002
13:30 - 14:00	0.0091 (0.0009)	94.3**	-0.0018 (0.0013)	1.88	-------	----	--------	----	-------	-----	-------	---	------	----	------	-----	--------	-------	2.25	0.015

Standard Error in Parentheses

! = Significant at the 10% level
* = Significant at the 5% level
** = Significant at the 1% level

Table XII.A

Regression Results of Intraday volatility(X 10^{-2}) of Second Nearest Eurodollar Futures Contract based on 15 minute interval returns of previous and non-expiration Fridays in a twelve day window around expiration.

(June 1982 - June 1987)

	Inter-cept	Chi-Sqr	Previous Friday	Chi Sqr	CU	Chi Sqr	FI	Chi Sqr	MTD	Chi Sqr	CPI	Chi Sqr	IP	Chi Sqr	PPI	Chi Sqr	EMP	Chi Sqr	GNP	Chi Sqr	DGO	Chi Sqr	D-W	R-Sqr
7:30 - 14:00 (N=1659	0.0155 (0.0006)	707.1**	0.0011 (0.0010)	1.21	0.0111 (0.0014)	0.67	0.0021 (0.008)	0.07	0.066 (0.020)	11.4**	0.0032 (0.008)	0.17	0.0007 (0 007)	0.01	0.029 (0.0046)	40.9**	0.0528 (0.0047)	127.3**	0.028 (0.014)	4.1*	-0.085 (0.014)	0.12	1.73	0.108
7:30 - 8:00 (n=147)	0.0191 (0.0034)	31.9**	0.0029 (0.0059)	0.24	—	—	—	—	0.066 (0.030)	5.0*	0.0002 (0.012)	0.00	—	—	0.0242 (0.0081)	8.9**	0.0493 (0.0078)	40.4**	0.0264 (0.021)	1.54	-0.087 (0.021)	0.11	1.79	0.284
8:15 - 8:45 (n=189)	0.0185 (0.0017)	112.3**	0.0039 (0.0031)	1.51	0.0067 (0.014)	0.23	—	—	—	—	—	—	-0.0051 (0.008)	0.42	—	—	—	—	—	—	—	—	1.80	0.010
9:00 - 9:30	0.0137 (0.0015)	80.3**	0.0022 (0.0028)	0.63	—	—	0.0028 (0.007)	0.14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.42	0.005
9:45 - 10:15	0.0132 (0.0009)	181.2**	-0.0007 (0.0017)	0.15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.98	0.001
10:30 - 11:00	0.0155 (0.0014)	118.4**	0.0008 (0.0025)	0.10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.60	0.001
11:15 - 11:45	0.0125 (0.0010)	170.9**	0.0004 (0.0017)	0.05	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.64	0.000
12:00 - 12:30	0.0131 (0.0013)	99.1**	0.0017 (0.0023)	0.57	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.52	0.001
12:45- 13:15	0.0152 (0.0016)	89.6**	0.0024 (0.0027)	0.79	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.44	0.012
13:30- 14:00	0.0206 (0.0025)	67.1**	-0.0003 (0.0043)	0.01	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.90	0.000

Standard Error in Parentheses

! = Significant at the 10% level
* = Significant at the 5% level
** = Significant at the 1% level

Table XII.B

Regression Results of Intraday volatility(X 10^{-2}) of Second Nearest Eurodollar Futures Contract based on 15 minute interval returns of previous and non-expiration Fridays in a twelve day window around expiration.

(Sept. 1987 - June 1992)

	Inter-cept	Chi-Sqr	Previous Friday	Chi Sqr	CU	Chi Sqr	FI	Chi Sqr	MTD	Chi Sqr	CPI	Chi Sqr	IP	Chi Sqr	PPI	Chi Sqr	EMP	Chi Sqr	GNP	Chi Sqr	DGO	Chi Sqr	D-W	R-Sqr
7:30 - 14:00 (N=1620)	0.0129 (0.0006)	471.6**	-0.0003 (0.0010)	0.10	0.0038 (0.0137)	0.08	-0.012 (0.019)	0.41	0.0179 (0.010)	2.97!	0.0206 (0.007)	7.6**	0.0216 (0.016)	1.86	0.0595 (0.0065)	84.1**	0.0667 (0.0054)	153.4**	0.0248 (0.009)	8.2**	0.0171 (0.019)	0.78	1.72	0.151
7:30 - 8:00 (n=180)	0.0254 (0.0046)	31.0**	-0.0097 (0.0080)	1.47	—	—	—	—	0.0180 (0.025)	0.53	0.0162 (0.018)	0.78	—	—	0.0555 (0.0161)	11.7**	0.0543 (0.0135)	16.3**	0.0123 (0.021)	0.35	0.0046 (0.046)	0.01	1.92	0.148
8:15 - 8:45	0.0143 (0.0013)	114.9**	0.0021 (0.0024)	0.72	-0.0005 (0.011)	0.00	—	—	—	—	—	—	0.0216 (0.012)	3.21	—	—	—	—	—	—	—	—	1.63	0.076
9:00 - 9:30	0.0121 (0.0013)	82.6**	0.0010 (0.0023)	0.18	—	—	-0.011 (0.015)	0.63	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.54	0.005
9:45 - 10:15	0.0116 (0.0010)	133.8**	-0.0006 (0.0017)	0.12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.95	0.001
10:30 - 11:00	0.0126 (0.0011)	121.3**	-0.0021 (0.0020)	1.06	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.80	0.006
11:15 - 11:45	0.0093 (0.0007)	198.7**	-0.0001 (0.0011)	0.02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.74	0.000
12:00 - 12:30	0.0102 (0.0009)	127.8**	0.00124 (0.0016)	0.63	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.86	0.003
12:45- 13:15	0.0101 (0.0011)	84.5**	0.0027 (0.0019)	2.10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.58	0.012
13:30- 14:00	0.0125 (0.0011)	124.9**	0.0022 (0.0019)	1.28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.53	0.007

Standard Error in Parentheses

! = Significant at the 10% level
* = Significant at the 5% level
** = Significant at the 1% level

APPENDIX

MACROECONOMIC ANNOUNCEMENTS

Title	Code	Usual Time(Central)	Number of Releases (June 1982 - June 1987)					
			Friday(-6)	Monday(-5)	PFriday(-1)	XMonday(0)	Friday(+4)	Monday(+5)
Consumer Price Index	CPI	7:30 a.m.	0	0	0	0	7	0
Durable Goods Order	DGO	"	0	0	0	0	2	0
Employment	EMP	"	17	0	0	0	0	0
Gross National Product	GNP	"	0	0	0	0	2	0
Merchandise Trade Deficit	MTD	"	0	0	1	2	0	0
Producer Price Index	PPI	"	1	0	18	0	1	0
Capacity Utilization	CU	8:15 a.m.	0	0	1	8	1	0
Industrial Production	IP	"	0	0	7	1	0	0
Factory Inventory	FI	9:00 a.m.	0	0	5	4	0	0

Title	Code	Usual Time(Central)	Number of Releases (Sept 1987 - June 1992)					
			Friday(-6)	Monday(-5)	PFriday(-1)	XMonday(0)	Friday(+4)	Monday(+5)
Consumer Price Index	CPI	7:30 a.m.	0	0	7	1	1	0
Durable Goods Order	DGO	"	0	0	0	0	6	0
Employment	EMP	"	15	0	1	0	0	0
Gross National Product	GNP	"	0	0	0	0	1	0
Merchandise Trade Deficit	MTD	"	0	0	4	0	0	0
Producer Price Index	PPI	"	2	0	9	0	1	0
Capacity Utilization	CU	8:15 a.m.	0	0	7	0	0	0
Industrial Production	IP	"	0	0	6	1	0	0
Factory Inventory	FI	9:00 a.m.	1	0	0	2	0	0

Source: Business Weeks " The Week Ahead " section, 1982-1992.