Public Information and Fixed Income Volatility

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Abstract

This paper analyzes the link between public information and price volatility in the short-term fixed income market. Our results indicate that the high market volatility observed at the opening of trading on the Eurodollar and Treasury bill futures contracts in the U.S. is due to U.S. macroeconomic announcements. When specific news releases are studied, we find that volatility is positively correlated with the magnitude of the surprise and is higher for bad news than for good news. We also conduct a detailed examination of the specific Fed actions and their market effects during the crash of October 1987.
1. **Introduction**

Market volatility is induced by the combined influence of trading structure and information arrival. In this paper, we examine the impact of public information disclosures on market volatility in the Eurodollar (ED) and the Treasury bill (TB) futures markets. Our study ranges from a broad treatment of the sources of information to a historically unique announcement that is related to the (reverse) crash of October 1987 in the fixed income markets.

We focus on market volatility induced by the public release of U.S. macroeconomic information. Our results show that U.S. macroeconomic disclosures are important determinants of trading-time to non-trading time volatility ratios. The high volatility in the Chicago Mercantile Exchange’s (CME) ED and TB contracts during the first hour of trading from 7:30am to 8:30am Central Time (CT) also coincides with the time major economic announcements are made. By examining the structural features of the ED futures traded on the London Financial Futures Exchange (LIFFE), we are able to infer that the increased volatility is distinct from volatility associated with trading procedures at the opening. Further analysis distinguishes between expected and unexpected announcements and focuses on the exact time of specific macroeconomic announcements. Our results reveal that the level of volatility is higher for bad news and increases with the magnitude of the surprise. Finally, we trace the price fluctuations that were initiated by a Federal Reserve Bank announcement during the crash of October 1987.

Our analysis is made possible by the availability of several data sources. For fixed income securities, we use the transaction data on ED and TB futures contracts that are traded on the CME and the ED futures contracts traded on the LIFFE. To examine the impact of
individual public information announcements on fixed income volatility, we search the Dow Jones News Retrieval database for the exact time and the magnitude of major macroeconomic announcements. We also use the survey data from Money Market Services to obtain market expectations. These expectations are used to calculate forecast errors or surprises that are in turn used to relate the magnitude of unanticipated announcements to the level of market volatility.

The remainder of the paper is organized as follows. Section 2 describes the ED and the TB futures markets. Section 3 lists the predictions of public information hypotheses for intraday and interday volatility configurations. Section 4 reports the empirical results. Section 5 offers some concluding remarks.

2. *The markets for fixed income futures contracts*

With the availability of transaction data on equities, considerable attention has focused on the role of private and public information in influencing the volatility of stock returns. While the dollar volume of trading in fixed income securities greatly exceeds the dollar volume of equity trading, little is known about the volatility of fixed income instruments. One of the main difficulties with fixed income instruments is their lack of homogeneity. A 90-day Treasury bill becomes an 89-day bill the following day and the volatility of a discount instrument usually decreases as the time to maturity shortens. In addition, the market for off-the-run issues may be illiquid. However, with the advent of futures trading, it is possible to study, in a highly liquid market, volatility patterns of fixed income instruments while holding the time to maturity constant.
This paper uses transaction data to study the interday and intraday volatility patterns in the market for 90-day Eurodollar deposits and 90-day Treasury bills. The ED and the TB futures are traded on the International Monetary Market (IMM) of the CME with the ED futures routinely trading $100 billion a day. Eurodollar contracts are also traded on the LIFFE, in Singapore, and in Tokyo. We use data from both the Chicago and the London exchanges for the ED futures. Our sample period for the CME extends from December 10, 1981 to May 10, 1988 for a total of 1266 daily observations. Our transaction data for the LIFFE cover the January 2, 1986 to December 29, 1989 period for a total of 716 daily observations.

The ED contracts on the CME and the LIFFE are virtually identical. The unit of trading is a $1 million certificate of deposit issued by a London-based bank. There are four delivery months: March, June, September and December. The final day of trading is the second business day before the third Wednesday of the delivery month in London. Prices are quoted as 100 minus the annualized interest rate. Currently, the CME Eurodollar trades between 7:20am and 2:00pm CT. Trading is halted at 9:30am CT on the last trading day of the expiring contract. The LIFFE contract trades between 8:30am and 4:00pm Greenwich Mean Time (GMT). There is a second session between 4:25pm and 6:00pm using the Automated Pit Trading System. However, the data from this second session are unavailable.

The only substantial difference between the LIFFE and the CME contracts occurs on the settlement date. Both contracts settle in cash and the final settlement price is the three-month London Interbank Offer Rate (LIBOR). However, the CME and the LIFFE bank surveys are

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1 Britain's Daylight time is in effect from the last Sunday in March to the last Sunday in October while U.S. Daylight Savings Time begins the first Sunday in April and ends the last Sunday in October.
different. With the CME, two surveys are conducted on the last trading day. For both surveys, 12 banks are randomly selected from a list of at least 20 London banks. The first survey takes place an hour and a half before the close. The second survey takes place at the close. The two high quotes and the two low quotes are discarded from each survey and the remaining 16 quotes are used to determine the average spot LIBOR.

The LIFFE conducts its own survey that takes place before the survey administered by the CME. Specifically, the LIFFE settlement price is based on the interest rate for three-month Eurodollar deposits being offered to prime banking institutions between 9:30am and 11:30am GMT on the last trading day by a random sample of 16 banks. The three highest and lowest quotes are discarded, and the settlement price is computed as 100 minus the annualized average of the remaining 10 rates. Due to the timing difference and to different survey methods, the CME and LIFFE contracts are not perfectly correlated.²

We also examine TB futures that are traded on the CME. The TB futures contract calls for delivery of 90-day TBs with a face value of $1 million at the expiration of the contract. The delivery months are the same as those for the ED futures. The final day of trading is the second business day before the third Wednesday of the delivery month. Prices are quoted in percentages as 100 minus the annualized discount yield. From December 10, 1981 to October 17, 1984, TB futures opened at 8:00am CT. On October 18, 1984 the opening time was rolled back to 7:30am CT and on October 15, 1985 the TB opening time was moved to 7:20am CT. Trading is halted at 1:30pm CT before maturity and at 9:30am CT on the last trading day of the

² Burghardt, et al. (1991) indicate another difference between the CME and the LIFFE contracts. If the CME survey produces an average LIBOR of 8.125%, the rate is rounded to 8.13 and the contract is settled at (100.00-8.13)=91.87. However, on the LIFFE, an average LIBOR of 8.125% is used to calculate a price of (100.00-8.125)=91.875 which is rounded to 91.88.
expiring contract. The TB and the ED futures prices are closely correlated and the contracts are
highly substitutable with one another.

3. Public Information and market volatility

The linkage between market volatility and information is addressed in numerous
theoretical studies.³ Ross (1989) provides a formal link between an asset’s price volatility and
the arrival of information that is not contingent on any specific asset pricing model. He
demonstrates that the volatility of price changes is identical with the rate of information arrival
in an arbitrage-free economy. A direct implication of Ross’s model in the presence of public
information is that prices are more volatile when public disclosures occur during the time
markets are open.

There are also numerous empirical papers on the impact of public information on market
volatility. French and Roll (1986) examine the relative importance of public information, private
information, and pricing errors in explaining the higher volatility in equity returns during
exchange trading hours relative to non-trading hours.⁴ If the higher volatility is due to public
information disclosures during normal business hours when the stock exchanges are open,
trading-time variances should not fall when exchanges are closed on business days. French and
Roll examine exchange holidays that occur when the New York and American Stock Exchanges
were closed on Wednesdays during the second half of 1968 because of paperwork backlogs.
Contrary to the public information hypothesis, they find that the variance of the two-day

³ See, for example, Admati and Pfleiderer (1988), Foster and Viswanathan (1990), and Wang
(1993).

⁴ See also Oldfield and Rogalski (1980).
exchange holiday returns is only 14.5% higher than the variance for normal one-day returns. However, an absence of significant macro information releases on Wednesdays may also contribute to the low exchange holiday return variances. In addition, public announcements tend to be concentrated at certain times. Thus, it is important to conduct both an interday and an intraday analysis of market volatility.

Jones, Kaul, and Lipson (1992) examine market volatility during trading and non-trading times when exchanges are open. Their results suggest that public news disclosures play an important role in determining volatility even during non-trading times.

In some markets, the effect of informed trading may be naturally mitigated. Harvey and Huang (1991, 1992) argue that the role of informed traders can be minimized by studying foreign currency futures contracts that are traded in highly efficient parallel markets around the clock. In this setting, the impact of private information trading on any particular exchange trading time to non-exchange trading time is limited as informed traders are free to trade based on their information in any time zone. Moreover, it is unclear as to who the privately informed traders are in the foreign currency markets. They find that U.S. dollar exchange rates are more susceptible to U.S. public news whereas the volatility of European cross-rates is influenced more heavily by public information disclosed during European business hours.

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5 French and Roll (1986) also examine election holidays, but the prediction of the public information hypothesis for exchange closings on elections days is unclear.


7 A recent study of stock index futures contracts by Becker, Finnerty, and Friedman (1992) finds that elevated U.K. return volatility is attributable to the release of U.S. public information.
3.1 Public information hypothesis and fixed income volatility

The large number of event studies in finance and accounting attests to the interest in examining the behavior of market prices to public dissemination of firm-specific information. Since the firm-specific event is often widely dispersed across calendar time, this research analyzes market reaction to a particular announcement in event time. In contrast, the relevant information for fixed income securities tends to have economy-wide implications and to be publicly disclosed at regularly scheduled times.

The ED and TB futures markets provide an exceptional opportunity to study the behavior of market volatility induced by the release of public information. The results supplement the evidence on public information trading obtained with foreign currency futures where it is important to differentiate market volatility induced by news emanating from both sides of the Atlantic. We begin by considering three hypotheses that associate market volatility with news disclosures without pinpointing the specific announcements responsible for the volatility.

First, the ED futures contracts are traded on the CME, the LIFFE, and on other exchanges, but the relevant market-wide public news emerges primarily during U.S. trading hours. Therefore, trading time volatility should exceed non-trading time volatility.

Second, the majority of the U.S. economy-wide announcements occur between 7:30am and 8:30am CT when both the CME and the LIFFE are open. Therefore, the public information hypothesis would predict higher return variances on both the CME and the LIFFE at the time of U.S. macroeconomic announcements. Since the U.S. announcements tend to be concentrated on Thursdays and Fridays, an interday and intraday analysis should reveal higher variances between 7:30am and 8:30am CT on these days.
Third, we have an opportunity to further confirm that the volatility is induced by public information by using data from the LIFFE. When major U.S. macroeconomic announcements are released between 1:30pm to 2:30pm GMT, the LIFFE is still in session and it is possible to trade ED futures in London. Therefore, market volatility on the LIFFE should be elevated at the time of the announcements and not during the opening.

In the next three hypotheses, we consider the influence of individual announcements. In efficient markets, only the unexpected component of an announcement induces trading that generates market volatility. Therefore, it is important to identify the anticipated component of the announcements and our inferences are conditional on the assumed expectations.

First, we test the prediction that market volatility is induced by the release of individual announcements. Unfortunately, most of the announcements occur at the time of exchange openings, preventing an examination of pre-announcement patterns. Fortunately, industrial production is a major macroeconomic announcement that is released consistently after the opening at 8:30am CT. Second, we determine whether the magnitude of the surprise is positively correlated with the level of market volatility.8

Third, a study of the crash of October 1987 has the advantage that it is generally regarded as a total surprise. Before trading began on the Tuesday following the market crash of Monday, October 19, 1987, the Federal Reserve Bank made the extraordinary announcement that it would provide liquidity in the market. The market impact that follows should be robust with respect to misspecification of the expectation process.

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8 Ederington and Lee (1992) also consider the impact of individual macroeconomic news announcements on interest rate futures markets. Specifically, they attempt to explain the elevated volatility between 7:30 to 7:35am CT in the futures market by announcements that are released before 7:30am CT. However, they do not distinguish between expected and unexpected announcements.
3.2 Summary

The following testable implications proceed from a highly general definition of public information to a specific public announcement.

1. Hourly variances during trading-time of ED and TB futures contracts listed on the CME exceed non-trading hourly variances because of the presence of public information trading during exchange hours.

2. Volatilities of the CME for ED and TB futures are elevated during the opening hour of trading because of macroeconomic announcements that occur before the opening. The highest volatilities are observed on Thursdays and Fridays, the days with the highest frequency of market-wide disclosures.

3. Volatilities on the LIFFE for ED futures are elevated at the time of U.S. macroeconomic announcements between 1:30pm and 2:30pm GMT.

4. Market volatility is induced by specific macroeconomic announcements.

5. The level of market volatility increases with the magnitude of the surprise.

4. Empirical results

The empirical analysis proceeds in four stages, progressing from a broad classification of the sources of public information to a unique announcement by the Federal Reserve Bank. The different stages of our analysis impose increasingly demanding restrictions implied by public information hypotheses on the data.

4.1 Volatility during exchange and non-exchange intervals

Although ED futures are traded in a number of markets, the Chicago and the London exchanges generate the highest volumes. The ED trading opens on the Singapore International
Monetary Exchange (SIMEX) at 9:45pm CT (7:45am local time) and continues until 7:20am CT.\textsuperscript{9} Trading on the LIFFE begins at 2:30am CT and continues until 10:00am CT. The CME opens at 7:20am CT and trades until 2:00pm. There is no exchange trading of Eurodollar futures between 2:00pm and 9:45pm.

There are three reasons to suspect that volatility during the CME trading time is higher than volatility during non-CME trading time. First, most government announcements of economic statistics are released during the first hour of CME trading. Trading volatility is generated as investors update their portfolios to reflect this new information. Although the underlying security in the futures contract is based in London, U.S. economic news leads to increased trading volatility of the ED deposits as the contract is specified in U.S. dollars. Second, the Federal Reserve Bank conducts its open market operations during U.S. business hours.\textsuperscript{10} Finally, the non-CME trading time includes the period of no futures trading (2:00pm to 9:45pm).

The last column in Table 1 presents ratios of hourly volatility rates during CME trading time and non-CME trading time for the entire CME sample from December 10, 1981 to May 10, 1988. The variances are calculated from returns, computed as $(r_{t}/r_{t-1})-1$, by using the transaction price that is closest to the close and the open. The nearby contract is used until one week before expiration day when we switch to the next-out contract. The return from the roll-

\textsuperscript{9} SIMEX trading began in 1984. These contracts are fungible with those traded on the CME so that contracts opened on one exchange may be liquidated on the other exchange. The time refers to Central Standard Time. During Daylight Savings Time, SIMEX is 13 hours ahead of the CME.

\textsuperscript{10} Harvey and Huang (1993) examine the impact of open market operations on market volatility.
over day to the following day is calculated using only the next-out contract.\textsuperscript{11}

To perform statistical inference on the variance rate ratio, French and Roll (1986) average subperiod ratios to obtain the standard errors. Instead, we use a generalized method of moments (GMM) approach that has several advantages.\textsuperscript{12} Most notably, our approach involves only one step. Additionally, GMM requires only weak distributional assumptions and permits inference procedures that are robust to departures from normality and heteroskedasticity in large samples. Specifically, we estimate the following system of equations:

\begin{equation}
\begin{align*}
    u_{1t} &= r_{co,t} - \mu_{co} \\
    u_{2t} &= r_{oc,t} - \mu_{oc} \\
    u_{3t} &= (r_{co,t} - \mu_{co})^2 \theta/17.5 - (r_{oc,t} - \mu_{oc})^2/6.5
\end{align*}
\end{equation}

where \( r_t \) is the return at time \( t \), \( \mu \) denotes the mean of the returns, \( \theta \) represents the variance rate ratio, \( oc \) and \( co \) are open to close and close to open respectively, and 17.5 and 6.5 denote the number of hours the CME is closed and open respectively. This framework provides a heteroskedasticity-consistent test of the null hypothesis that the variance rate ratios are significantly different from one.

The results in Table 1 are reported for the days of the week and for all days. There is an extremely influential observation in the denominator of the Tuesday ratio. This is the variance from the close on Monday October 19, 1987 to the open on Tuesday October 20, 1987.

\textsuperscript{11} Conceptually, the return may not be defined given the ability to enter the futures contract without any initial investment. Nevertheless, the variance of relative price changes facilitates cross-contract comparisons of price changes and is a return volatility if the full value of the contract is placed in a non-interest bearing margin account. The computation of hourly volatility rates also assumes that returns are serially uncorrelated.

\textsuperscript{12} Related applications are in Harvey and Huang (1991) and Ferson and Harvey (1992).
Before the opening of trading on October 20, the Federal Reserve announced that it would provide liquidity in the market. By the opening of trading on October 20, the annualized Eurodollar yield decreased by more than 200 basis points. This single observation greatly increases the non-exchange trading variance that appears in the denominator and causes the reduction in the ratio. Therefore, we report variance rate ratios with and without the October 20, 1987 observation.

Panels A and B display the results for the ED and TB futures respectively. For the full sample, the ED and TB futures are approximately two and half times more volatile during U.S. business hours than non-exchange hours. When the ratios are calculated by days of the week, Tuesday ratios are the lowest of the week. They represent the volatility of returns from Monday’s open to Monday’s close divided by the volatility of returns from Monday’s close to Tuesday’s open. Although the Tuesday ratios increase when October 20, 1987 observation is excluded, they are still the lowest of the week. The low ratios may be influenced by the Treasury auctions that occur on Mondays with the settlement prices revealed at 6:00pm on Mondays.\footnote{See Cammack (1991) for an analysis of the information in Treasury auctions.} Aside from the Tuesday ratios, all the variance rate ratios in Table 1 are significantly different from one.

Trading to non-trading time variance rate ratios for ED futures traded on the LIFFE are reported in Panel A Table 2. The LIFFE trading-time overlaps with the morning trading in Chicago when most U.S. macroeconomic disclosures occur. The LIFFE non-trading time includes the final 3.5 hours of CME trading and the 7.5 hours before the market reopens in Singapore. Therefore, one would expect trading to non-trading variance rate ratios to be greater
than one. The table shows that LIFFE trading time variances are 1.3 times larger than non-trading time variances. Similar to the CME's ED ratio for Tuesday, the LIFFE's Tuesday ratio is less than one. At the open on Tuesday October 20, 1987, the LIFFE's ED price opened 73 points higher. This observation has the same effect of increasing the denominator and reducing the rate ratio. When this observation is excluded, the variance rate ratio for Tuesday increases to 1.4 from 0.9.

Panel B covers the January 2, 1986 to May 10, 1988 subsample of the CME data that overlaps with the available LIFFE data. During this subperiod, it is important to exclude the observation of October 20, 1987 since its effect would be even more pronounced given the smaller sample size. The \( \theta \) column shows that when this observation is excluded, the trading time variance is 2.7 times higher than the non-trading time variance which is consistent with the overall sample reported in Table 1. By way of contrast, it is still much smaller than the value of 16.2 for U.S. common equity found by Stoll and Whaley (1990) even at this higher variance rate ratio.

A direct comparison of the LIFFE and the CME volatility is also presented in Table 2. Panel B reports the CME trading time to the LIFFE trading time variance rate ratio under column \( \phi \). The variance rate ratio for all days excluding October 20, 1987 indicates that CME's ED futures are 1.8 times more volatile than those traded on the LIFFE. Although both the CME and the LIFFE are opened during the period when most U.S. macroeconomic news is released, the LIFFE trading hours do not include Fed time. Thus, the Federal Reserve Bank activities may account for the lower volatility in the London market.
4.2 Opening time and market volatility

Most public information releases occur between 7:30am and 8:30am CT. If volatility increases are associated with these releases, we should observe high volatility during the opening hour on the CME for ED and TB contracts. Table 1 presents hourly variances by day of the week and by hours of the day for the entire CME sample. The variances are obtained by estimating the following model:

\[ u_{1t} = r_t - \mu \]
\[ u_{2t} = (r_t - \mu)^2 - \sigma^2 \]  

(2)

where \( r_t \) is the open to 8:30 return or open to close return, \( \mu \) is the mean estimate, \( \sigma^2 \) denotes the variance estimate, and \( u \) is the disturbance term. This method allows us to calculate heteroskedasticity-consistent standard errors of the parameters.

The results reveal that the volatilities at the open are the highest for all days of the week and for both ED and TB futures. In addition, the opening volatilities are highest on Thursdays and Fridays which is consistent with a concentration of U.S. macroeconomic disclosures observed on these days.\(^{14}\) To provide a further perspective on the magnitude of the opening volatilities, Table 1 also provides the open-to-close variances. The opening volatilities on Thursdays and Fridays account for over 35% of the trading time variances.

The use of LIFFE data provides further evidence on the public information hypothesis. Given the timing of U.S. public information releases, increased volatility should occur between 1:30pm and 2:30pm GMT and not during the opening on the LIFFE. Panel A in Table 2 documents the intraday volatility patterns on the LIFFE. The magnitude and the significance

\(^{14}\) This evidence suggests that the LIFFE reacts to U.S. news announcements rather than the routine opening of U.S. trading and provides evidence against the argument made in King and Wadhwani (1990).
of the volatilities in Table 2 show that volatility more than triples on the LIFFE during the time of U.S. macroeconomic announcements between 1:00pm and 3:00pm GMT. Additionally, Fridays have the highest volatility on the LIFFE at the time when there is a concentration of U.S. public disclosures.\textsuperscript{15}

Amihud and Mendelson (1987) and Stoll and Whaley (1990) find that the higher opening volatility on the New York Stock Exchange may be induced by the periodic clearing procedures used at the open that differ from the continuous auction mechanism employed after the opening. Amihud and Mendelson (1991) examine the possibility that the higher opening volatility may in fact be due to the long period of no trading preceding the opening.\textsuperscript{16} This alternative hypothesis is questionable for our sample since a single open outcry auction method is used for the opening as well as subsequent trades on the CME, and trading of the ED contract can be accomplished on the LIFFE before the CME opens.

Panel B of Table 2 provides the results for the CME’s ED futures traded during the same sample period. The conclusions reached in Table 1 for CME’s TB and ED futures for the entire sample hold for the subperiod in Table 2 as well. In particular, volatility concentrations occur at the open, averaging 60% of the daily volatility on Thursdays and Fridays. Since announcements occur while the LIFFE is in session, these opening volatilities cannot be attributed to the opening procedures.

\textsuperscript{15} Harvey and Huang (1991) and Becker et al. (1992) show that over 60% of the major announcements occur on Thursdays and Fridays. Ekman (1990) also provides an analysis of intraday ED futures.

\textsuperscript{16} Forster and George (1992) find evidence that favors the preceding nontrading period explanation instead of the NYSE opening mechanism for the higher open-to-open return variances for NYSE securities.
4.3 *Individual macroeconomic announcements and market volatility*

In this section, we relate market volatility to specific news releases. Since this necessitates the specification of market expectations, the analyses test a joint hypothesis of public information and market expectations. Specifically, we examine seven economy-wide announcements and their impact on futures volatility. Consumer price index, gross national product, industrial production, index of leading indicators, producer price index, retail sales, and unemployment are generally regarded by traders as being major announcements. However, only industrial production figures are released well after the opening on the CME. The exact time of the announcements is obtained from the Dow Jones News Retrieval database. We also compute forecast errors or surprises calculated as actual minus expected. This allows us to determine whether the magnitude of the surprise is systematically related to market volatility. The market's expectations are obtained from surveys conducted by Money Market Services.

The results for all the announcements except the industrial production disclosures are reported in Table 3 for the October 18, 1984 to May 10, 1988 period. The starting date corresponds to the time the TB opening time was moved to 7:30am CT from 8:00am CT. Starting on October 15, 1985, the opening interval widens to 25 minutes since both the ED and the TB open at 7:20am CT. Table 3 presents the variances obtained by estimating the system of equations (2). The variances are grouped into three categories: open-to-close, open-to-7:45am CT, and open-to-7:45am CT for three levels of surprises. In the last category, the surprise levels correspond to absolute surprises [0.0, 0.2], (0.2, 0.4], and greater than 0.4. If there is more than one announcement on a particular day, we choose the biggest surprise.

In the first half of Table 3, all six announcements are examined together. The results
show substantial increases in volatility on days with the announcements. On days with announcements, ED futures are 2.3 times more volatile during the trading hours and 3.9 times more volatile during the opening interval. The TB futures are 1.7 times more volatile during the trading hours and 2.8 times more volatile during the opening interval. A comparison of the trading hours volatilities with the opening volatilities shows that opening variances account for almost a third of the daily variances for the ED and the TB futures contracts on days when the announcements are made.

The third category in Table 3 presents the level of volatility as a function of market surprise during the opening time interval. We observe higher variances for bigger surprises. For surprises of at least 0.4, the variances exceed the average variances for all surprises reported in the second category.

The bottom half of Table 3 repeats the analysis for the two inflation announcements, the consumer price index and the producer price index.17 Again, higher volatilities are observed for both the interest rate contracts during the opening interval and the entire trading time when inflation figures are released. However, the percentage increase in opening variances is lower than for the combined six announcements. The evidence is also consistent with the null hypothesis that market volatility rises with increased inflation surprises.

Table 4 contains the results for industrial production announcements that occur during the December 16, 1981 to April 15, 1988 period. The figures are released primarily at 8:30am CT but some are released as early as 8:15am and some as late as 8:43am. The first part of the table reports the 15-minute intraday volatility patterns. The variances are calculated with the

17 These announcements never occur on the same day since the PPI is always released one day before the CPI.
system of equations (2). To test the null hypothesis that the variance in the 8:30 to 8:45 interval is equal to the other variances, we estimate the following system of equations:

\[
\begin{align*}
    u_{1t} &= r_{jt} - \mu_j \\
    u_{2t} &= r_{kt} - \mu_k \\
    u_{3t} &= (r_{jt} - \mu_j)^2 - \sigma_j^2 \\
    u_{4t} &= (r_{kt} - \mu_k)^2 - \sigma_k^2
\end{align*}
\] (3)

where \( j \) and \( k \) represent different time intervals. When we restrict the variances to be equal, \( \sigma_j^2 = \sigma_k^2 \), the system is over-identified and yields a chi-square statistic with one degree of freedom.

The ED volatility results reveal a humped pattern with an elevated opening interval that is due to the influence of other announcements. The hump occurs at the 8:30am to 8:45am time slot when most industrial production figures are released. The 8:30am to 8:45am volatility is significantly different from all the other variances except at the opening. The TB volatility pattern also exhibits high opening volatility followed by a hump pattern with the hump occurring at the expected time. However, the two 15-minute variances from 8:00am to 8:30am also appear elevated and are insignificantly different from the 8:30am to 8:45am variance.

The second part of Table 4 contains regression results. To determine whether volatility is related to the magnitude of the surprises, we estimate the following equation:

\[
r_t^2 = \alpha + \beta_1 E_t^2 + \beta_2 DE_t^2 + \epsilon_t
\] (4)

where \( r_t^2 \) denotes the squared return at time \( t \), \( E_t^2 \) represents the squared forecast error, and \( DE_t^2 \) is the product of \( E_t^2 \) and an indicator variable that equals one when the forecast error is greater than zero. The indicator variable is included to capture any asymmetric behavior towards good news (positive surprises) and bad news (negative surprises).
The regression results are reported in Table 4. Similar evidence is obtained for both the ED and the TB futures, but the results for the TB futures are stronger. In general, volatility increases are associated with bigger surprises. Perhaps more interestingly, the $\beta_2$ coefficients measure the incremental effect on return volatility when there are positive surprises or good news. Both the $\beta_2$ coefficients are highly significantly negative, suggesting that market volatility is higher for bad news than for good news in the case of industrial production.

4.4 The reverse crash of 1987

The previous section focuses on regular individual public announcements. This section examines the impact of a one-of-a-kind public announcement made by the Fed. Given the atypical nature of the announcement, it can be construed as news. Thus, it avoids the disadvantage of the analyses in the previous sections that are conditional on the proper formulation of market expectations.

Much has been written on the crash of 1987, but the focus has been primarily directed at the behavior of the equity markets. For example, Schwert (1990) studies equity volatility patterns during October 1987 and provides a historical perspective by examining other episodes of high volatility. While the equity market was crashing, the fixed income market was rallying. For our study, the crash observations are extremely influential and we have presented results with and without October 20, 1987. We now examine the crash of October 1987 in greater detail.

The intraday ED futures prices on the CME and on the LIFFE for October 19-20, 1987 are plotted in Figure 1. On October 19, both the CME's and the LIFFE's ED futures prices are fairly stable in the 90.40 range with the CME drifting higher in the last hours of trading. The
market expected an announcement from the Federal Reserve Chairman Alan Greenspan although the content of the statement was unknown. The LIFFE’s ED opened at 91.10, up 73 points from its close, and drifted upward throughout the morning of the 20th. However, in the 15 minutes before the CME opened, the LIFFE price shot up from 91.70 at 7:04am CT to 92.30 at 7:24am CT. Not coincidentally, Federal Reserve Chairman announced at 7:15am CT that "the Federal Reserve affirmed today its readiness to serve as a source of liquidity to support the economic and financial system" (Crutsinger 1987).

Figure 1 shows that the LIFFE’s and the CME’s ED futures prices move very closely together. Their close proximity to one another was maintained by cross-exchange arbitrage. However, at the open on October 20, the CME’s ED traded at 92.70 which amounted to a 216 basis point increase from the previous close.¹⁸ To put this move in perspective, with a margin of $1500, the overnight price move meant a gain of $5400 for the long contract.

At the CME open on October 20, there is an unprecedented 50 basis point gap between the CME and the LIFFE contract that quickly disappears. In the first five minutes of trading, the CME contract plunges 70 points. The situation is now reversed: the LIFFE is at 92.30 and the CME at 92.00. By 7:30am CT, both contracts are trading at 92.00.

There are wide fluctuations in the ED price on October 20. By 8:15am, the Eurodollar is trading at 92.20 on both the CME and LIFFE. However, by 8:45am, the price plummets to 91.45. In the next few hours, prices moves higher and coincides with active market intervention by the Federal Reserve. The CME contract moves to 92.40 by 11:05am and eventually retreats to 91.80 at the close. Although not reported in the graph, an analysis of Wednesday October

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¹⁸ There are no trading limits on either the LIFFE’s or the CME’s ED contracts.
21 reveals no unusual spreads between the LIFFE and CME contracts. The CME contract moved within a 40 point band and the LIFFE contract within a 22 point band. While these movements are still volatile, they are small compared to the price swings of the previous day.

5. **Conclusions**

This study analyzes the impact public information has on volatility in short-term interest rate markets. Our focus ranges from a broad prediction of market volatility being different during exchange trading hours to specific actions taken by the Federal Reserve Bank during the market break of October 1987. Our intraday analysis reveals that volatility is higher during CME trading hours than non-CME trading hours. The CME trading hours coincide with the release of major economics news and a significant amount of volatility is concentrated during the opening hour of CME trading. The latter coincides with the time when most macroeconomic news is released. This concentration is not due to opening procedures since our analysis of the LIFFE volatility shows a concentration of volatility around the CME opening -- not the LIFFE opening.

Using data on specific macroeconomic news announcements, we confirm that the opening volatility is driven by surprises. The results show that about 30% of the entire day's volatility is accounted for during the opening 15 minutes of trading on days with news announcements. We also find that higher variances are associated with larger forecast errors. There is one news announcement, industrial production, that is untainted by the opening since it is consistently released well after the opening of trading. The fifteen-minute variances rise at the time of this news release and bad news appears to be associated with higher volatility than good news.
Finally, we examine the market crash of 1987 from the perspective of the short-term fixed income market. At 7:15 CT October 20, the Chairman of the Federal Reserve Bank issued a one sentence statement indicating that the Fed would provide liquidity. Using data from the LIFFE (which was trading at the time), we find that the immediate impact of this announcement was a 60 point gain on the ED contract and greatly increased volatility.
References


Crutsinger, Martin, 1987, Fed pledges to protect banks in market plunge, Associated Press, October 20, 11:17 EDT.


Ekman, Peter D., 1990, Intraday and weekly patterns in the IMM Eurodollar futures market: Marketplace and marketwide effects, Working paper, Kansas State University, Manhattan, Kansas.


Forster, Margaret and Thomas J. George, 1992, Volatility, trading mechanisms and international cross-listing, Working paper, Ohio State University, Columbus, OH.


Harvey, Campbell R. and Roger D. Huang, 1992, Information and volatility in the FX market, Finanzmarkt und Portfolio Management 6, 14-22.


Jones, Charles M, Gautam Kaul and Marc L. Lipson, 1992, Information, trading and volatility, Working paper, University of Michigan, Ann Arbor, MI.


Figure 1

The Market Break of October 19-20, 1987
Liffe and CME Eurodollar Futures in Five Minute Intervals

October 19, 1987       October 20, 1987
Volatility in the Chicago Mercantile Exchange's Eurodollar and Treasury bill futures markets

The model estimated is:

\[ u_{it} = r_{t} - \mu \]
\[ u_{2t} = (r_{t} - \mu)^2 - \sigma^2 \]

where \( r_{t} \) is the open to 8:30 return or the open to close return, \( \mu \) is the mean estimate, \( \sigma^2 \) is the variance estimate, and \( u \) is the disturbance term. The system is exactly identified.

The variance ratio, \( \theta \), is obtained by estimating the following system:

\[ u_{1t} = r_{co,t} - \mu_{co} \]
\[ u_{2t} = r_{oc,t} - \mu_{oc} \]
\[ u_{3t} = (r_{co,t} - \mu_{co})^2/17.5 - (r_{oc,t} - \mu_{oc})^2/6.5 \]

where \( oc \) and \( co \) represent open-to-close and close-to-open respectively. 17.5 and 6.5 represent the number of hours the exchange is closed and open respectively.

<table>
<thead>
<tr>
<th>Day</th>
<th>Obs.</th>
<th>Open-8:30</th>
<th>Open-Close</th>
<th>( \theta )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Varoc/6.5</td>
</tr>
<tr>
<td>Monday</td>
<td>312</td>
<td>3.655</td>
<td>13.520</td>
<td>0.750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.543)</td>
<td>(1.945)</td>
<td>(0.311)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>333</td>
<td>5.343</td>
<td>11.538</td>
<td>1.099</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.563)</td>
<td>(1.958)</td>
<td>(0.404)</td>
</tr>
<tr>
<td>Tuesday*</td>
<td>332</td>
<td>4.071</td>
<td>11.366</td>
<td>3.162</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.914)</td>
<td>(1.954)</td>
<td>(0.494)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>331</td>
<td>3.539</td>
<td>11.220</td>
<td>2.202</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.538)</td>
<td>(1.662)</td>
<td>(0.571)</td>
</tr>
<tr>
<td>Thursday</td>
<td>326</td>
<td>11.019</td>
<td>22.780</td>
<td>5.967</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.877)</td>
<td>(6.038)</td>
<td>(1.745)</td>
</tr>
<tr>
<td>Friday</td>
<td>320</td>
<td>5.258</td>
<td>15.162</td>
<td>2.338</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.543)</td>
<td>(2.255)</td>
<td>(0.492)</td>
</tr>
<tr>
<td>All days*</td>
<td>1621</td>
<td>5.544</td>
<td>14.838</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.792)</td>
<td>(1.460)</td>
<td></td>
</tr>
</tbody>
</table>

| **B: Treasury bill, December 10, 1981-May 10, 1988** |      |           |            |             |
| Monday      | 307  | 3.271     | 14.299     | 1.433       |
|             |      | (0.564)   | (2.358)    | (0.425)     |
| Tuesday     | 332  | 3.143     | 9.910      | 1.901       |
|             |      | (0.670)   | (1.442)    | (0.449)     |
| Tuesday*    | 331  | 2.729     | 9.812      | 3.160       |
|             |      | (0.527)   | (1.445)    | (0.522)     |
| Wednesday   | 330  | 2.974     | 10.375     | 3.158       |
|             |      | (0.414)   | (1.392)    | (0.331)     |
| Thursday    | 320  | 4.376     | 12.183     | 3.135       |
|             |      | (0.935)   | (1.519)    | (0.840)     |
| Friday      | 313  | 4.242     | 11.869     | 2.622       |
|             |      | (0.518)   | (1.500)    | (0.603)     |
| All days*   | 1601 | 3.531     | 11.696     |             |
|             |      | (0.282)   | (0.750)    |             |

The variances are those of the relative price changes calculated as \( (p_t/p_{t-1}) - 1 \) and are multiplied by 10,000,000. The nearby contract is used until one week before expiration when we switch to the next-out contract. Beginning October 18, 1984 the Treasury bill opening was moved back from 8:00 CT to 7:30 CT. On October 15, 1985, both the Eurodollar and Treasury bill openings were moved back to 7:20 CT. * represents parameters estimated without the October 20, 1987 observation. Standard errors in parentheses are heteroskedasticity consistent.
An international comparison of Eurodollar futures market volatility

The model estimated is:

\[ u_{1t} = r_t - \mu \]
\[ u_{2t} = (r_t - \mu)^2 - \sigma^2 \]

where \( r_t \) is the vector of returns over different time intervals, \( \mu \) is the vector of mean estimates, \( \sigma^2 \) is the vector of variance estimates, and \( u \) is the vector of disturbance terms with unconditional zero means. The system is exactly identified.

The variance ratio, \( \theta \), for the CME Eurodollar is obtained by estimating the following system:

\[ u_{1t} = r_{oc,t} - \mu_{oc} \]
\[ u_{2t} = r_{oc,t} - \mu_{oc} \]
\[ u_{3t} = (r_{oc,t} - \mu_{oc})^2 \theta / 17.5 - (r_{oc,t} - \mu_{oc})^2 / 6.5 \]

where \( oc \) and \( co \) represent open-to-close and close-to-open respectively. 17.5 and 6.5 represent the number of hours the CME is closed and open respectively. For the LIFFE, these hours are 16.5 and 7.5.

<table>
<thead>
<tr>
<th>Day</th>
<th>Obs.</th>
<th>Open- 9:30</th>
<th>9:30- 10:30</th>
<th>10:30- 11:30</th>
<th>11:30- 12:30</th>
<th>12:00- 1:00</th>
<th>1:00- 2:00</th>
<th>2:00- 3:00</th>
<th>3:00- Close</th>
<th>Open- Close</th>
<th>( \theta )</th>
<th>[ \frac{\text{Var}<em>{oc}/7.5}{\text{Var}</em>{co}/16.5} ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>106</td>
<td>0.595</td>
<td>0.261</td>
<td>0.167</td>
<td>0.221</td>
<td>0.158</td>
<td>0.485</td>
<td>0.521</td>
<td>0.501</td>
<td>2.058</td>
<td>0.422</td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>117</td>
<td>0.743</td>
<td>0.824</td>
<td>0.533</td>
<td>0.361</td>
<td>1.724</td>
<td>2.073</td>
<td>1.544</td>
<td>1.632</td>
<td>10.721</td>
<td>0.214</td>
<td></td>
</tr>
<tr>
<td>Tuesday*</td>
<td>116</td>
<td>0.645</td>
<td>0.291</td>
<td>0.142</td>
<td>0.169</td>
<td>0.181</td>
<td>1.110</td>
<td>0.650</td>
<td>0.751</td>
<td>2.906</td>
<td>0.886</td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td>118</td>
<td>0.442</td>
<td>0.260</td>
<td>0.131</td>
<td>0.362</td>
<td>1.251</td>
<td>1.316</td>
<td>0.925</td>
<td>0.924</td>
<td>2.745</td>
<td>1.416</td>
<td></td>
</tr>
<tr>
<td>Thursday</td>
<td>115</td>
<td>0.273</td>
<td>0.107</td>
<td>0.197</td>
<td>0.268</td>
<td>0.922</td>
<td>0.928</td>
<td>0.744</td>
<td>0.828</td>
<td>2.294</td>
<td>1.487</td>
<td></td>
</tr>
<tr>
<td>Friday</td>
<td>113</td>
<td>0.286</td>
<td>0.177</td>
<td>0.157</td>
<td>0.218</td>
<td>3.624</td>
<td>2.121</td>
<td>1.191</td>
<td>1.482</td>
<td>6.652</td>
<td>1.515</td>
<td></td>
</tr>
<tr>
<td>All days*</td>
<td>568</td>
<td>0.449</td>
<td>0.212</td>
<td>0.187</td>
<td>0.178</td>
<td>0.244</td>
<td>1.491</td>
<td>1.119</td>
<td>0.830</td>
<td>3.348</td>
<td>1.311</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Day</th>
<th>Obs.</th>
<th>8:30- 8:30</th>
<th>Open- Close</th>
<th>[ \frac{\text{Var}<em>{oc}/6.5}{\text{Var}</em>{co}/17.5} ]</th>
<th>[ \frac{\text{Var}<em>{cme}/6.5}{\text{Var}</em>{fe}/7.5} ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>116</td>
<td>0.859</td>
<td>3.874</td>
<td>(0.160)</td>
<td>(0.756)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>123</td>
<td>4.642</td>
<td>3.735</td>
<td>(3.380)</td>
<td>(0.710)</td>
</tr>
<tr>
<td>Tuesday*</td>
<td>122</td>
<td>1.268</td>
<td>3.262</td>
<td>(0.365)</td>
<td>(0.526)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>122</td>
<td>2.455</td>
<td>5.357</td>
<td>(0.696)</td>
<td>(1.292)</td>
</tr>
<tr>
<td>Thursday</td>
<td>119</td>
<td>3.863</td>
<td>5.179</td>
<td>(2.434)</td>
<td>(8.607)</td>
</tr>
<tr>
<td>Friday</td>
<td>116</td>
<td>3.688</td>
<td>8.607</td>
<td>(0.544)</td>
<td>(2.484)</td>
</tr>
<tr>
<td>All days*</td>
<td>595</td>
<td>2.430</td>
<td>5.252</td>
<td>(0.535)</td>
<td>(0.631)</td>
</tr>
</tbody>
</table>


The variances are those of the relative price changes calculated as \( \left( \frac{p_t}{p_{t-1}} \right) - 1 \) and are multiplied by 10,000,000. The nearby contract is used until one week before expiration when we switch to the next-out contract. Beginning October 18, 1984 the Treasury bill opening was moved back from 8:00 CT to 7:30 CT. On October 15, 1985, both the Eurodollar and Treasury bill openings were moved back to 7:20 CT. * represents parameters estimated without the October 20, 1987 observation. Standard errors in parentheses are heteroskedasticity consistent.
The model estimated is:

\[
\begin{align*}
\epsilon_{1t} &= r_t - \mu \\
\epsilon_{2t} &= (r_t - \mu)^2 - \sigma^2
\end{align*}
\]

where \( r_t \) is the return measured over the open-to-7:45 CT interval or the open-to-close interval, \( \mu \) is the estimate of the mean, \( \sigma^2 \) is the estimate of the variance, and \( \epsilon \) is the disturbance term which should have an unconditional mean of zero. The system is exactly identified.

<table>
<thead>
<tr>
<th>Announcements</th>
<th>Contract</th>
<th>Open-to-close variance</th>
<th>Open-to-7:45 CT variance</th>
<th>Open-to-7:45 CT variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>no</td>
<td>for all announcements</td>
<td>no</td>
</tr>
<tr>
<td>Six major</td>
<td>Eurodollar</td>
<td>5.302 (0.412)</td>
<td>12.072 (1.931)</td>
<td>0.964 (0.112)</td>
</tr>
<tr>
<td>announcements</td>
<td>Observations</td>
<td>697</td>
<td>202</td>
<td>697</td>
</tr>
<tr>
<td>Six major</td>
<td>Treasury bill</td>
<td>5.216 (0.562)</td>
<td>8.866 (1.452)</td>
<td>1.158 (0.115)</td>
</tr>
<tr>
<td>announcements</td>
<td>Observations</td>
<td>691</td>
<td>199</td>
<td>691</td>
</tr>
<tr>
<td>Inflation</td>
<td>Eurodollar</td>
<td>5.986 (0.427)</td>
<td>14.503 (4.040)</td>
<td>1.397 (0.149)</td>
</tr>
<tr>
<td>announcements</td>
<td>Observations</td>
<td>814</td>
<td>85</td>
<td>814</td>
</tr>
<tr>
<td>Inflation</td>
<td>Treasury bill</td>
<td>5.593 (0.521)</td>
<td>10.027 (2.936)</td>
<td>1.547 (0.167)</td>
</tr>
<tr>
<td>announcements</td>
<td>Observations</td>
<td>805</td>
<td>85</td>
<td>805</td>
</tr>
</tbody>
</table>

The six major announcements are consumer price index, producer price index, retail sales, gross national product, unemployment, and the index of leading indicators. The variances are those of the relative price changes calculated as \( (p_t/p_{t-1}) - 1 \) and are multiplied by 10,000,000. The nearby contract is used until one week before expiration when we switch to the next-out contract. The sample starts October 18, 1984 when the Treasury bill opening was moved from 8:00 CT to 7:30 CT. On October 15, 1985 both the Eurodollar and Treasury bill openings were moved back to 7:20 CT. Hence, the open-to-7:45 CT interval widens to 25 minutes. * represents parameters estimated without the October 20, 1987 observation. Standard errors in parentheses are heteroskedasticity consistent.
Table 4
Return volatility during industrial production announcements
December 16, 1981–April 15, 1988

A: Intraday volatility linked to the announcement of industrial production.

The model estimated is:

\[ u_{1t} = r_{jt} - \mu_j \]
\[ u_{2t} = (r_{jt} - \mu_j)^2 - \sigma_j^2 \]

where \( r_{jt} \) is the return over time interval \( j \), \( \mu_j \) is the estimate of the mean, \( \sigma_j^2 \) is the estimate of the variance, and \( u \) is the disturbance term which should have an unconditional mean of zero. The system is exactly identified.

The test of variance equality is obtained by estimating the following system:

\[ u_{1t} = r_{jt} - \mu_j \]
\[ u_{2t} = r_{kt} - \mu_k \]
\[ u_{3t} = (r_{jt} - \mu_j)^2 - \sigma_j^2 \]
\[ u_{4t} = (r_{kt} - \mu_k)^2 - \sigma_k^2 \]

where \( j \) and \( k \) represent the different time intervals. The system is overidentified by one restriction (which is the degrees of freedom in the \( \chi^2 \) test). The numbers in brackets under the \( \chi^2 \) statistics are p-values.

<table>
<thead>
<tr>
<th>Time</th>
<th>Eurodollar Variance</th>
<th>( \chi^2 )</th>
<th>( \sigma_{2,30-45}^2 = \sigma_i^2 )</th>
<th>Treasury bill Variance</th>
<th>( \chi^2 )</th>
<th>( \sigma_{2,30-45}^2 = \sigma_i^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:30-7:45</td>
<td>2.317 (0.501)</td>
<td>0.539 (0.466)</td>
<td>1.685 (0.479)</td>
<td>3.211 (0.073)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:45-8:00</td>
<td>0.635 (0.148)</td>
<td>7.226 (0.005)</td>
<td>0.606 (0.193)</td>
<td>0.173 (0.677)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:00-8:15</td>
<td>0.825 (0.128)</td>
<td>5.208 (0.022)</td>
<td>1.963 (0.697)</td>
<td>0.466 (0.499)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:15-8:30</td>
<td>0.678 (0.162)</td>
<td>6.444 (0.011)</td>
<td>0.967 (0.284)</td>
<td>1.188 (0.275)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:30-8:45</td>
<td>1.880 (0.438)</td>
<td>1.424 (0.325)</td>
<td>1.219 (0.486)</td>
<td>2.941 (0.086)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:45-9:00</td>
<td>0.654 (0.149)</td>
<td>7.228 (0.007)</td>
<td>0.819 (0.188)</td>
<td>9.357 (0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00-9:15</td>
<td>0.726 (0.208)</td>
<td>5.750 (0.016)</td>
<td>0.422 (0.075)</td>
<td>0.003 (0.999)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:15-9:30</td>
<td>0.297 (0.062)</td>
<td>12.271 (0.000)</td>
<td>0.538 (0.100)</td>
<td>6.827 (0.008)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:30-9:45</td>
<td>0.485 (0.177)</td>
<td>8.141 (0.004)</td>
<td>0.462 (0.125)</td>
<td>7.238 (0.007)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:45-10:00</td>
<td>0.310 (0.068)</td>
<td>12.616 (0.000)</td>
<td>0.405 (0.096)</td>
<td>9.454 (0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00-10:15</td>
<td>0.361 (0.067)</td>
<td>11.006 (0.001)</td>
<td>0.313 (0.063)</td>
<td>9.990 (0.002)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B: Estimation of

\[ \text{Return}_t^2 = \alpha + \beta_1 (\text{Error}_t^2) + \beta_2 (\text{Dum}_{t|\text{Error}_t>0} \times \text{Error}_t^2) + \epsilon_t \]

<table>
<thead>
<tr>
<th>Contract</th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \bar{R}^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eurodollar</td>
<td>1.617 (0.521)</td>
<td>20.572 (12.676)</td>
<td>-20.803 (12.605)</td>
<td>0.043</td>
</tr>
<tr>
<td>Treasury bill</td>
<td>1.000 (0.469)</td>
<td>31.296 (14.216)</td>
<td>-27.283 (14.086)</td>
<td>0.190</td>
</tr>
</tbody>
</table>

The variances are those of the relative price changes calculated as \( (pt/pt-1) - 1 \) and are multiplied by 10,000,000. The nearby contract is used until one week before expiration when we switch to the next-out contract. Beginning October 18, 1984 the Treasury bill opening was moved back from 8:00 CT to 7:30 CT. Therefore, the first two variances for the Treasury bill contain only 42 observations. There are 77 observations for all other the intraday variances. On October 15, 1985 both the Eurodollar and Treasury bill opening were moved back to 7:20 CT. The opening variance is estimated with a 25 minutes return. While most of the industrial production announcements are released at 8:30, they have been released as early as 8:15 and as late as 8:41 CT. Hence, in the regression in Panel B, the squared return measured 15 minutes before and 15 minutes after the announcement is used. All standard errors in parentheses are heteroskedasticity consistent.