Public Information, Price Volatility and Trading Volume in US Bond Markets[1]

Dungey, M.[*], Frino, A.[**] and McKenzie, M.D.[*,***]

Abstract

Prices in bond markets have been noted as moving extremely rapidly following macroeconomic news announcements – with a delayed increase in trading volume. New data allows us to demonstrate that the previously unexplained dichotomy between rapid price and sluggish volume movement in the US Treasuries cash market originates with rapid price *and* volume change in the Treasury futures market. Consistent with research in other markets, the Treasury futures lead price discovery in the cash market.

[1] We are grateful to Lyudmyla Hvozdyk and Tugrul Vehbi for outstanding research assistance. This paper was partly written while Frino was a visitor at CFAP, University of Cambridge.
[*] CFaP, University of Cambridge
[**] Faculty of Economics and Business, University of Sydney.
[***] RMIT University. Corresponding author. Ph. +613 9925 5858 Fax: +613 9925 5986 Email: michael.mckenzie@rmit.edu.au

1. Introduction

The market axiom that "it takes volume to make prices move" has important implications for financial markets and asset price behaviour.[2] As such, a considerable theoretical and empirical literature has evolved that investigates the nature of the relationship between trading volume and price dynamics.

The theoretical literature focuses on the sequential information arrival hypothesis and the mixture of distributions hypothesis, both of which imply a positive relationship between volume and price changes (see Kocagil and Shachmurove, 1998, for discussion). Testing of these two theories has produced mixed findings and many papers conclude that both may possess explanatory power (see, inter alia, Mahieu and Bauer, 1998, Darrat, Rahman and Zhong, 2003 Li and Wu, 2006, Darrat, Zhong and Cheng, 2007).

The early empirical research on this issue suggests that while the causality implicit in the adage is questionable, a relationship between prices and volume exists for a wide variety of assets and markets (see Karpoff, 1987, for a survey). More recent research however, suggests that the nature of the relationship is complex. For example, Jones, Kaul and Lipson (1994) find that it is the number of transactions and not trading volume that is important. Xiaoqing and Wu (1999) conclude that both the frequency of transactions and the average trade size are important factors in explaining return volatility.

More importantly, a number of papers have questioned the significance and nature of the relationship between volatility and volume. For example, Chan and Fong (2000) find that when controlling for order imbalance, the relationship between volume and volatility is less pronounced. In a related paper, Daigler and Wiley (1999) distinguish between different types of traders and conclude that the trading activities of the general public, who do not have access to order flow information, are responsible for the positive relationship between volume and volatility. Other papers have also pursued this theme of asymmetric information and have produced results that call into question the assumed nature of the relationship between volatility and volume. For example, Li and Wu (2006) argue that the relationship between volatility and volume is driven by the informed component of trading. They control for information flow and find that volatility is negatively related to trading volume. Kiymaz and Berument (2003) generate a similar result in their study of daily data for five major stock market indices sampled. They find that the days with the highest volatility typically have the lowest trading volume. Foster and Viswanathan (1990) argue that this negative relationship is the result of liquidity traders leaving the market in periods of high volatility.

This issue is further complicated by the evidence of Fleming and Remolona (1999) who find that prices may move in the absence of trading volume around

[2] The importance of volume in understanding price dynamics is highlighted by the research of Lamoureaux and Lastrapes (1990) who find that volume can account for the presence of ARCH effects. Subsequent research however, suggests that volatility clustering may persist even when volume is considered (see Fleming, Kirby and Ostdiek, 2006, and Gillemot, Farmer and Lillo, 2006).

macroeconomic information releases.[3] They examine the impact of macroeconomic news announcements on US bond markets.[4] Goodhart and O'Hara (1997) argue that bond markets present an ideal environment for this type of study as they are the most important financial market for transmitting news on macroeconomic conditions. Fleming and Remolona (1999) find that the arrival of macroeconomic news to the market produces a near instantaneous price change with a corresponding reduction in volume. Thus, Fleming and Remolona (1999, p 1902) conclude that "price reactions to public information do not require trading".

The purpose of this paper is to revisit the findings of Fleming and Remolona (1999) and reassess the role of volume in bond price discovery. We argue that an empirical study that focuses on the physical bond markets response to news announcements does not fully capture the dynamics of the bond price discovery process. Specifically, the trading cost hypothesis suggests that informed traders will choose to exploit their informational advantage in the futures market (see *inter alia* Kawaller, Koch and Koch, 1987, and Stoll and Whaley, 1990, Fleming, Ostdiek and Whaley, 1996). Thus, bond price discovery will take place, not in the cash market, but in futures markets. Brandt, Kavajecz and Underwood (2006) Chung, Campbell and Hendry (2007) and the evidence presented in this paper, all provide evidence of the importance of futures markets in bond price discovery.

In this paper, we empirically assess the price and liquidity of US Treasury bond and bond futures markets at the time of important macroeconomic news releases. We argue that price discovery takes place in the futures market where the standard positive volume and volatility responses to news are expected. The physical bond market observes the response of the futures market to the news and adjusts prices to restore equilibrium. This cash market price response however, will take place in the absence of any significant increase in trading volume. This is because the markets response to the news is revealed to the cash market, not by its own trading, but by the trading of informed participants in the futures market.

To test this hypothesis, we focus on high frequency data for the 10-year US Treasury bond sampled over the period January 2, 2002 to September 29, 2006. The bond price data is sourced from the Cantor-Fitzgerald eSpeed database and a full description of this data may be found in Dungey McKenzie and Smith (2007). Data for the 10 year Treasury futures market for the same sample period is sourced directly from Reuters. Using this data, we investigate the price and trading volume response to major macroeconomic news announcements. The results suggest that a large increase in bond price volatility is observed in the minute immediately following a news announcement and volatility remains high. While an increase in trading activity is observed in the minute of the news release, a much large response is observed in the minute following the news release. These results do not however, mean that it does

[3] Kalimipalli and Warga (2002) study US corporate bonds and find volatility is positively related to spreads and volume is negatively related to spreads.

[4] Fleming and Remolona form a part of a much larger literature that looks at the impact of scheduled macroeconomic news announcements on the stock market (see inter alia Pearce and Roley, 1983, 1985, French and Roll, 1986, McQueen and Roley, 1993, Sun and Tong, 2000), the foreign exchange rate market (see inter alia Ito and Roley, 1987, Hardouvelis, 1988, Ederington and Lee, 1994, DeGennaro and Shreives, 1997, Almeida, Goodhart and Payne, 1998), and the bond market (see inter alia Becker, Finnerty and Kopecky, 1996, Jones, Lamont and Lumsdaine, 1998, Fleming and Remolona, 1999a).

not take volume to move bond prices. To understand why, the role of the Treasury futures markets need to be considered. In this paper, we examine the trading response of 10-year Treasury futures to macroeconomic news announcements and find that futures price volatility increases at the time of the announcement. More importantly, an immediate and large jump in futures trading intensity and volume is observed in the minute of the announcement. Thus, the old adage applies, however in this case it might more aptly be stated as "it takes futures trading volume to move bond prices".

2. Treasury Market Data

Until recently, most US bond market research has relied on data from the GovPX database, see Fleming (1997) for an overview. However, in more recent years the voice over protocol which GovPX represents has been largely replaced by electronic trading, see Mizrach and Neely (2006a), dominated by the eSpeed service of Cantor Fitzgerald and BrokerTec, now owned by ICAP. Data from these two sources has recently become available, and research is emerging to characterise the market; see particularly Mizrach and Neely (2006a,b), Fleming and Mizrach (2007), Dungey, McKenzie and Smith (2007), Jiang, Lo and Verdelhan (2007).[5] A consequence of comparing results across these databases is that either the BrokerTec or eSpeed data can be judged as representative of the market, each having around half the market, although it is difficult to be precise about their exact market share.

In this paper, on-the-run 10-year US Treasury bond data is sourced from the Cantor Fitzgerald eSpeed trade database beginning with the first available observation on January, 2 2002 to September 29, 2006.[6] The data has been filtered to remove US public holidays leaving a sample of 1,241 days with over 4000 trades per day and an average daily trading volume of over $US18 billion in this maturity.

Figure 1 plots the daily closing 10-year bond price over the sample period. The defining feature of this period are the cycle in monetary policy, which eased from the beginning of the sample to the bottom of the cycle in 2003. There was considerable uncertainty about the future direction for monetary policy in 2003, punctuated by a series of FOMC statements with wording which gradually changed from considering the threat of potential deflation in mid-2003 to finally adopting a more positive outlook for growth and concerns over positive future inflation in 2004. Each of the major drops in bond prices seen in 2003-2004 in the figure correspond with changes in sentiment towards monetary policy (specifically the dates relate to market reaction to FOMC statements after the meetings on June 24-25, 2003 and December 9, 2003; see the FOMC minutes for meetings held on August 12, 2003 and January 27-28, 2004 for analysis of the impact of the previous meetings). Once the direction of monetary policy was firmly re-established in 2004 the general trend is for a slow fall in bond futures prices, with two major interruptions shown. These interruptions are evident in the bond prices on the figure as March 2005 and May 2006. These also relate to monetary policy decisions; specifically, the March 22, 2005 FOMC statement accompanying the decision to raise the federal funds rate and the rise in the federal funds rate on May 10, 2006 (see the FOMC minutes for meeting on May 3,

[5] It is a measure of how recently the new databases have become available that most of the papers characterising the data have only emerged in the last year.

[6] A trading day is defined as starting at 07:30 and finishing at 17:30, where all time references are US EST denoted with a 24 hour clock.

2005 and June 28-29, 2006 respectively). The last incident was also associated with higher than anticipated inflation figures released in the period. For most of the sample the 10 year bond was the longest US Treasury maturity regularly receiving new issuance – there were no issues in the 30 year bond market from August 10, 2001, before the sample begins, until February 16, 2006. This resulted in a premium for the 10 year bond as many market players have had high demand for long dated securities to offset long run liabilities.

We characterise the bond market response to macroeconomic announcements using a minute by minute observation interval around the time of these announcements and compare them to an equivalent set of data sampled across non-announcement days. The sample data consists of observations on price and volume in one minute intervals. This is constructed by taking the price of the last trade occurring in each minute as representative of the price in that minute. Additionally we collect data on the total volume and number of trades in each minute. Returns to the 10-year bond are calculated as the log change of the last traded price in each minute interval. The volatility of these price changes is proxied by the standard deviation of the returns observed for a given interval.

A wide variety of regularly scheduled macroeconomic announcements occur throughout the year. The Appendix presents a summary of the 48 main news items available from Bloomberg including their source, frequency and the time of their release. This information is used to categorise the sample period into non-announcement and announcement days. For the sample of 1,241 trading days, 1,366 announcements occurred on 1,060 days leaving a sample of 181 non-announcement days. It is interesting to note that a large number of announcements occur across all of the days-of-the-week, although a bias does exist towards announcements being made in the second half of the week. More specifically, 12% of all announcements occurred on a Monday, 19% occurred on a Tuesday or a Wednesday, 23% occurred on a Thursday and 27% on a Friday.

This study is limited to the most important macroeconomic news items. Following Fleming and Remolona (1999), the producer price index, consumer price index and employment announcements are selected, as the literature has found them to have a significant impact on the Treasury market (see also Fleming and Remolona, 1997, Balduzzi, Elton and Green, 2001). Specifically, the non farm payrolls data (NFP) are compiled by the Bureau of Labor Statistics and released at 8:30 A.M. (EST) in the first week after month-end. National consumer price index (CPI) data (U.S. city averages) are released each month by the Bureau of Labor Statistics at 08:30 (EST), approximately 2 weeks after the reference period. Finally, information relating to the producer price index (PPI), also compiled by the Bureau of Labor Statistics, is released at 08:30 (EST) on or near the day preceding the release of the CPI figures. Of the 1,366 announcements made during the sample period, there were 170 announcement days related to PPI, CPI or NFP.

Returning to the sample data we further refine the data set to the one-minute returns, volume and number of transactions for the period 8:25 to 8:36EST on each of the announcement days (containing PPI, CPI or NFP news) on which trading occurs (168

days)[7], and days on which no announcements occurred (181 days). In the remainder of this paper these will be called the announcement and non-announcement days respectively.

Descriptive statistics for this data as well as the trading volume and intensity are presented in Table 1. The mean one minute return over the period is 0.015085 with a standard deviation of 0.835 (ie. 0.0835%). The largest return is 1.7025%. The largest negative price movement is a price fall of -1.7869%. The returns data clearly fails the Jarque-Bera test of normality.

This one minute cash market data is matched to a corresponding database of US 10-year Treasury bond futures data for the same announcement and non-announcement days and the same 1 minute intervals. This futures contract trades on the Chicago Board of Trade in CST which is one hour behind EST, so that timestamps in this sample are adjusted accordingly. The contract is for one unit of the underlying with a face value of US$100,000 and a minimum time to maturity of 6.5 years. The contract expires quarterly on a March rotation and the last trading day is the seventh business day preceding the last business day of the delivery month. Settlement is by physical delivery of the underlying asset.

A plot of bond futures prices is also presented in Figure 1 and, as expected, the two series are highly correlated. Returns are calculated as log price changes and descriptive statistics for returns, trading volume and trading intensity in the futures market are presented in Table 1. The mean futures return (0.015169) is similar to that in the cash market, while the standard deviation (0.775) is lower. The futures returns series also fails the Jarque-Bera test of normality.

3. The Price Response of US 10-Year Bonds to Macroeconomic News

Panel A of Table 2 documents the behaviour of price volatility for macroeconomic announcement and non-announcement days. For the days on which PPI, CPI and NFP announcements are made, the average level of price volatility in the 08:25-08:26 interval is actually lower than for the non-news days, ie. 0.182 compared to 0.222 respectively. The ratio of announcement day to non-announcement day standard deviations in this interval is 0.820. As the time to announcement draws closer however, the price volatility of the announcement day data increases such that in the trading interval immediately prior to the announcement, the volatility has increased threefold. The non-announcement day price volatility however remains constant across the same period of time. Thus, the standard deviation ratio has increased from 0.820 to 2.641 in the minute immediately prior to the announcement minute. The F-statistic shown in the final row of panel A in Table 2 shows that the differences between the volatilities in the announcement and non-announcement days are statistically significant.

At the time of the announcement, the price volatility of the announcement days increases by over 500% to 2.910, whereas no discernible change in the non-announcement day price volatility is evident in the announcement minute or any other

[7] On 2 of the 170 days in the sample containing a PPI, CPI or NPF announcement either the bond or futures data were incomplete, leaving 168 days in the announcement sample.

following trading interval. The standard deviation ratio increases to 13.043 in the announcement minute and falls successively thereafter. This trend is driven by the spike in price volatility on announcement days in the 1-minute interval immediately following 08.30. While the level of observed volatility decreases in each interval, it does not fall to its preannouncement levels by the time of the last trading interval at 08:35-08:36 and the standard deviation ratio remains above 2. Thus, there is clear evidence of large price movements in the 1-minute trading interval immediately after 08.30, driven by the release of CPI, PPI and NFP macroeconomic news.

Panel B of Table 2 presents the average aggregate trading volume within each 1-minute trading interval for announcement and non-announcement days. On non-announcement days, the aggregate trading volume is 31.028 contracts on average in the 08.25-08.26 interval. This is 15.325 contracts less than the average aggregate trading volume on macro news announcement days in the same interval (46.353). As the 08.30 trading interval draws nearer, the average trading volume in the non-announcement data remains fairly constant. The announcement day average volume estimate actually falls slightly in the interval immediately prior to 08.30 however, such that the difference in means falls to 10.925 in the 08.29-08.30 interval.

In the 08.30-08.31 trading interval, the average aggregate trading volume on announcement days increases by a factor of 3 to 128.633, while the average trading volume of the non-announcement days is typically the same in this (and all successive) interval(s). Thus, the difference in means rises to 95.581. In the next trading interval however, the average aggregate trading volume increases again such that the trading volume for announcement days in the 08.31-08.32 interval is an average of 172.237 contracts and the difference in means increases to 136.016. Thus, while the average aggregate trading volume does increase in the first minute following a macroeconomic news announcement, a greater level of trading volume is observed in the 08.31-08.32 interval. In fact, the average aggregate trading volume is greater in every 1-minute interval from 08.31 to 08.36 than in the minute immediately after the actual announcement. In all cases, the p-values from difference in means t-tests reported in the final row of Panel B shows that the volume traded on announcement and non-announcement days are statistically significantly different.

A summary of the average number of trades in each one minute interval in presented in Panel C of Table 1. For non-announcement days, the average number of trades ranges between 7 or 8 trades per minute. On announcement days, a similar number of trades is observed in the intervals leading up to the announcement. After the announcement however, the number of trades increases threefold to 31 in the 08.30-08.31 interval and similar levels of trading intensity are observed thereafter. As with the other metrics, the trading intensities are statistically significantly different across the announcement and non-announcement samples.

Thus, the 10-year bond market data suggests that on non-macroeconomic announcement days, the price volatility, trading volume and trading intensity do not vary much over the time period 08.25-08.36. Where a macro news announcement is released to the market however, a large increase in price volatility is observed in the

minute immediate following the announcement and volatility remains above preannouncement levels over the next five minutes of trading. The trading volume response to the macroeconomic news announcement however, does not necessarily coincide with the price movements. Specifically, while an increase in trading activity is observed in the minute of the news release, a much larger response is observed in the minute following the news release.

Compared with Fleming and Remolona (1999), we interestingly find that there are statistically significant differences in both volatility and volume for non-announcement and announcement days across each of the 10 one-minute periods examined. They find differences only after the announcement time. Some of this may be due to differences in classification of the non-announcement days, in their application non-announcement days are all days other than the CPI, PPI and NFP announcement days – and thus include all days of other macroeconomic news announcements. When we repeat the analysis here using this classification we also find that there is less difference between the announcement and non-announcement volumes and volatility in the five minutes prior to 8:30, although the differences remain statistically significant.

Fleming and Remolona considered only one year of data from August 1993. The focus in this paper on data sampled across the period 2002 to 2006 allows us to comment on the stability of the markets response to macroeconomic news. To this end, Tables 3 and 4 present a summary of the bond price volatility and trading intensity metrics for each year in the sample. Table 3 characterises the non-news days and in general, the volatility across the 8:25 to 8:35 time intervals in any given year is reasonably stable. There is some evidence of lower price volatility in 2006 and also the post 8:30 intervals for 2005. 2006 also exhibits a noticeably higher number of trades around the 8:30 interval, although no clear pattern is present in the trading volume estimates. The announcement day summary presented in Table 4 shows that the minute prior to the announcement has experienced greater volatility more recently. Further, the bond market price response to news is around twice as large in 2004 compared to any other year. The greater trading intensity observed in the non-announcement days for 2006 is also mirrored in these announcement day data. The number of trades in the minute after the announcement is twice as high in 2006 compared to all other years. Similarly, the trading volume in this interval is also noticeably higher in the announcement minute for 2006. While a part of the increased bond trading highlighted by these metrics reflects by greater market coverage of the Cantor database, it also serves to highlight the growth in the industry over the sample period, Mizrach and Neely (2006a) give an overview of the market growth during the transition from voice protocol to electronic trading in the last decade. The growth in the market is considered more fully in the futures data discussion in Section 4.

In general, these findings are consistent with Fleming and Remolona (1999) and extend their results to more recent time periods. One interpretation of these results is that it doesn't take volume to move bond prices: which is the conclusion of Fleming and Remolona (1999). In this paper however, we argue that to fully understand the nature of the price adjustment in bond markets around the time of macroeconomic news announcements, the role of the futures markets must be taken into account. We turn to this in the following section.

4. The Role of Futures Markets in Treasury Price Discovery

Panel A of Table 5 documents price volatility in Treasury bond futures around macroeconomic events. In the first trading interval of 08.25-08.26, the futures price volatility is lower on announcement days compared to non-announcement days. The futures price volatility increases across each successive trading interval however, such that the standard deviation ratio increases from 0.851 to 7.449 in the minute immediately prior to the announcement. This pattern is similar to that which is observed in the cash market, and at each minute interval the volatility in announcement days is statistically significantly higher than in non-announcement days, with p-values of the F-statistic reported in the final row of Panel A. However, in the futures data, the increase in price volatility immediately prior to the announcement is more pronounced. For the minute immediately prior to the announcement, the standard deviation ratio is 2.641 in the cash market, whereas it is 7.449 in the futures market.

In the first trading minute after the announcement, the price futures volatility increases to an average of 3.089 and this increase is similar to that observed in the cash market where price volatility rose to 2.910 (the standard deviation ratio of the futures market is 12.023, which is slightly less than the cash market ratio of 13.043). The jump in futures price volatility exhibits less persistence compared to the cash market however, as price volatility in the 08.31-08.32 interval is less than one, whereas the cash market did not return to this level for another two minutes.

The average aggregate futures trading volume in each interval is summarised in Panel B of Table 5. The level of futures trading is statistically significantly higher for announcement days compared to non-announcement days in every trading interval after 07.28. In particular, the minute immediately prior to the announcement exhibits a noticeable jump in trading volume in what appears to be some last minute position-taking by traders. The difference in means in the 08.29-08.30 CST is over 150% higher than the average for the previous four trading intervals. This increase in trading is minor however, when compared to the increase in futures trading in the minute of the news announcement. The aggregate trading volume for all announcement days increases almost six fold to an average of 10,219.549 contracts and the difference in means increases from 788.832 to 9,260.318 contracts. By way of contrast, the trading volume on non-announcement days is generally unchanged over this trading window. While the level of trading volume falls in the following minute to 7,280.445 contracts, it remains higher for the remainder of the sample period when compared to the levels of observed pre-08.30 trading volume. Again to compare the results with the Fleming and Remolona the analysis was also conducted with non-announcement days classified as all days not containing a CPI, PPI or NFP announcement. In this case there is no longer a statistically significant difference in volume traded between the announcement and non-announcement days prior to 8:29 although volume remains statistically significantly higher from 8:29 onwards.

The average number of trades (Panel C of Table 5) exhibits qualitatively similar behaviour to trading volume. That is, the average number of trades on announcement days is statistically significantly greater than on non-announcement days. Further, a jump in trading intensity is observed in the minute prior to 08.30, which is not

observed on non-news days. In the minute following an announcement, the number of trades increases over 500% to an average of 329 trades per minute and the trading intensity remains higher to the end of the observed trading intervals.

Tables 6 and 7 present a summary of this data by calendar year and many of the previously identified trends in the cash market data are also present in the futures market. That is, for the non-news days (Table 6), the volatility across the 8:25 to 8:35 time intervals in any given year is reasonably stable. There is some evidence of lower price volatility in 2005 and 2006, in particular for post 08:30 trading. The more recent years also exhibit a higher number of trades and trading volume. The news day data for the futures market (Table 7) shows that the pre-trading response to news is greatest in the 2004 data. Similarly, the volatility response to news announcements is also greatest in 2004 in both the minute immediately after the announcement and also the following trading intervals. The increasing trading intensity throughout the sample period is particularly pronounced in this futures data. The trading volume across all of the intervals has grown considerably such that in 2006, an average of five times more volume is observed in each interval compared to 2002. This increase in futures trading volume reflects an overall growth in the industry in general and reinforces the growth in the cash market data is not solely driven by increased coverage of the Cantor database. A final observation relates to the number of number of trades. Although trading volume is progressively higher each year in the sample, the number of trades is greatest in 2004. The news release interval in particular, exhibits a much larger number of trades compared to other intervals.

Thus, for the bond futures market, pre-announcement price volatility increases by more in comparison to the cash market. At the time of an announcement however, a similar increase in futures and cash price volatility is observed. The persistence of this volatility increase however, is greater in the cash market suggesting the futures market prices respond faster to the news. In addition to these differences in volatility, an important difference in futures trading volume and intensity is observed. That is, unlike the bond cash market, an immediate and large jump in trading volume and the number of trades is observed on announcement days. By way of contrast, the same set of trading measures do not exhibit any real change over the observed one-minute trading intervals.

4. Price Discovery in the Bond and Futures Markets

The central proposition of this paper asserts that the price response of the bond market to macroeconomic news begins in the futures market, where informed traders act on their information, and that this information is subsequently revealed through futures trading to the bond market. The analysis of Section 3 documents that price futures price volatility and trading intensity react to the release of new prior to the physical market. A statistical measure of this relationship is provided via a Granger causality test of the form:

$$R_{B,\tau,t} = \alpha + \sum_{i=1}^{p} \beta_i R_{B,\tau-i,t} + \sum_{i=1}^{p} \chi_i R_{F,\tau-i,t} + \varepsilon_{\tau,t} \qquad (1)$$

where $R_{B,\tau,t}$ is the return to the 10-year Treasury bond in the minute interval τ on day t. $R_{F,\tau,t}$ is the corresponding return to the futures contract. The number of lag terms considered here is $p=5$ to capture the full interval around 8:30 (in the analysis in this section the sample each day is extended to cover 8:20EST to 8:40EST each day). The Granger causality test that the futures market has no influence on the cash market is given by testing whether $\chi_i = 0$ for all i. The coefficients for equation (1) are presented in Panel A of Table 8. Each of the five lagged bond returns and futures returns are significant and the F-statistic of 518.802 strongly rejects the null of no Granger causality. Thus, the evidence provided by the Granger causality test suggests that the information content of futures market returns has explanatory power over the cash market.

Where markets are engaged in mutual monitoring, as is often the case for a physical and a derivative market, innovations to one market may, at least to some extent, feed though to the other. As such, it is possible that causality may be bi-directional and so it is appropriate to also test the hypothesis as to whether the bond market innovations impact on the futures market. In this case, Equation 1 may be respecified with the futures market return (ie. $R_{F,\tau,t}$) as the dependent variable. The estimated results are presented in Panel B of Table 8. The results show that only the 3-period lagged futures return is significant and none of the lagged cash market returns are significant at the 5% level. The F-test of the dependent variables is again significant (5.095), which rejects the null hypothesis of no Granger causality although it is a substantially smaller F-statistic compared to that for the test of the futures market leading the cash market.

Given the interactions between the bonds and futures markets documented we next consider a simple lead-lag relationship of the following form:

$$R_{B,\tau,t} = \omega + \sum_{i=-5}^{5} \phi_i R_{F,\tau-i,t} + \varepsilon_{\tau,t} \qquad (2)$$

that is, the return to the 10-year Treasury bond on day t at time τ is regressed against the leaded and lagged return to the futures contract. The estimated coefficients for Equation 2 and associated t-statistics are summarised in Panel A of Table 9.[8] The estimated coefficients indicate that the economic significance of the one period lagged and the contemporaneous future return in explaining the current period's cash market return is substantial. While the futures returns at other lags are also statistically significant, the estimated coefficients are relatively small. Wald tests presented at the bottom of Table 9, reject the null hypotheses that either the individual slope coefficients are zero or that the sum of the lagged slope coefficients is equal to zero.

For completeness, the lead-lag relationship is also estimated where the futures market is the dependent variable and the results are presented in Panel C of Table 9. The one and two period lagged cash market returns are significant in explaining the current period futures market return, as are the one and two period ahead terms. The most important term however, is the contemporaneous term. A Wald test fails to reject the

[8] Where the analysis is restricted to only consider non-announcement days, the results are qualitatively unchanged.

null hypothesis that the slope coefficients for the lagged variables are individually equal to zero however, the test that they are jointly equal to zero is rejected.

Consistent with existing literature the evidence here supports that the futures market return lead the cash market. The central focus of this paper is on whether this informational link is heightened on macroeconomic news days. To test this hypothesis, a dummy variable is introduced into Equation (2), D_{NEWS}, which takes a value of unity on news days as follows:

$$R_{B,\tau,t} = \omega + \sum_{i=-5}^{5} \phi_i R_{F,\tau-i,t} + \sum_{i=-5}^{5} \gamma_i D_{NEWS} R_{F,\tau-i,a} + \varepsilon_{\tau,t} \quad (3)$$

The estimated results are presented in Panel B of Table 9. The relative importance of the contemporaneous and one period lagged term found in Panel A is maintained and each of the lags remain individually and jointly significant. The t-statistics reported for the dummy variable coefficients, γ_i, show that only the first lag is significant on news days. The impact of the futures lag on the bonds is heightened by 50% on news days. Again the Wald tests support the individual and joint significance of the interaction terms between the news dummy and the lagged futures returns in bond returns.

Where Equation (3) is modified to include the futures return as the dependent variable and leaded and lagged bond market returns are the independent variables (Panel D of Table 9), none of the bond returns are significant in explaining current futures returns. Further, none of the lagged dummy variable terms are significant. The Wald test of coefficient equality finds that the five lagged terms are not jointly or individually significantly different from zero. Most importantly, the Wald test of the null of equality between the announcement and non-announcement day counterparts is insignificant. Thus, where news and non-news days are distinguished, no evidence of the bond market leading the futures market can be found. These results serve to reinforce the previous discussion that find in favour of the futures market in taking the lead role in price discovery for the bond market.

5. Conclusion

A substantial literature has developed that investigates the relationship between prices and volume. A particularly interesting contribution to this literature came from Fleming and Remolona (1999) who investigated the US Treasury market and found that prices may move in the absence of trading volume. In this paper, we reassess the role of trading volume in bond price discovery and argue bond price discovery takes place in the futures markets.

To test this hypothesis, we begin with 10-year bond data over the period 2002 to 2006. A sample of macroeconomic news announcement and non-announcement days is selected and summary statistics for 1-minute intervals around the 08.30 EST announcement time are presented. Announcement days are shown to have statistically significantly greater volatility and volume traded than non-announcement days. In non-macroeconomic announcement days, the price volatility, trading volume and

trading intensity do not vary much around the announcement time. Where a macro news announcement is released to the market however, a large increase in price volatility is observed in the minute immediate following the announcement and volatility remains high, in particular over the next two minutes of trading. While an increase in trading activity is observed in the minute of the news release, a much larger response is observed in the minute following the news release. In the absence of any further information, these results may be interpreted as suggesting that it doesn't take volume to move bond prices.

Recognising the potential for price discovery in the bond futures market, a matching database of 10-year Treasury futures price and trading information is sampled. An examination of this data reveals that for futures, announcement and non-announcement days also have statistically significantly greater volatility and volume in each one minute interval around 8:30 EST. As in the cash market an increase in futures and cash price volatility is observed at the time of an announcement. The persistence of this volatility increase however, is greater in the cash market suggesting the futures market prices respond faster to the news. Most importantly, an immediate and large jump in futures trading intensity and volume is observed in the minute following an announcement.

Thus, we conclude that bond markets do not possess a special set of price dynamics that distinguish them from other asset markets. Previous research that has considered the cash market in isolation does not tell the full story. Once the price discovery role of futures markets is taken into account, volume and price in bond markets are closely related.

Bibliography

Balduzzi, P., Elton, E.J. and Green, T.C. (2001) "Economic News and Bond Prices: Evidence from the US Treasury Market", Journal of Financial and Quantitative Analysis, 36 (4), 523-543.

Brandt, M.W., Kavajecz, K.A. and Underwood, S.E. (2007) "Price Discovery in the Treasury Futures Market", Journal of Futures Markets, Forthcoming.

Chan, K. and Fong, W-M. (2000) "Trade Size, Order Imbalance and the Volatility-Volume Relation" Journal of Financial Economics, 57 (2) 247 -

Chung, D., Campbell, B. and Hendry, S. (2007) "Price Discovery in Canadian Government Bond Futures and Spot Markets" Bank of Canada, Working Paper, 2007-4.

Daigler, R.T. and Wiley, M.K. (1999) "The Impact of Trader Type on the Futures Volatility-Volume Relation" The Journal of Finance, 54 (6) 2297 - 17

Darrat, A.F. Rhaman, S. and Zhong, M. (2003) "Intraday trading volume and return volatility of the DJIA stocks: A note" Journal of Banking and Finance, 27 (10) 2035 -

Darrat, A.F., Zhong, M. and Cheng, L.W.T. (2007) "Intraday volume and volatility relations with and without public news" Journal of Banking and Finance,31 (9) 2711 -

Dungey, M., McKenzie, M. and Smith, V. (2007) "Empirical Evidence on Jumps in the Term Structure of the US Treasury Market", manuscript, University of Cambridge.

Fleming, M.J. (1997) "The Round-the-Clock Market for U.S. Treasury Securities", FRBNY Economic Policy Review, 3 (2), 9-32.

Fleming, J., Kirby, C. and Ostdiek, B. (2006) "Stochastic Volatility, Trading Volume, and the Daily Flow of Information" The Journal of Business, 79 (3) 1551 –

Fleming, M.J. and Mizrach, B. (2007) "The Microstructure of a US Treasury ECN: The BrokerTec Platform", paper presented at the Third Central Bank Workshop on Market Microstructure, Budapest, September 14-15, 2007.

Fleming, J. Ostdiek, B. and Whaley, R.E. (1996) "Trading Costs and the Relative Rates of Price Discovery in Stock, Futures and Option Markets" The Journal of Futures Markets, 16 (4) 353-387.

Fleming, M.J. and Remolona, E.M. (1999) "Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information" Journal of Finance, 54 (5) 1901-1915.

Foster, F.D. and Viswanathan, S. (1990) "A theory of the interday variations in volume, variance, and trading costs in securities markets" Review of Financial Studies, 3 (4), 593-624.

Gillemot, L., Farmer, J.D. and Lillo, F. (2006) "There's more to volatility than volume" Quantitative Finance, 6 (5) 371 – 384.

Goodhart, C.A.E., and O'Hara, M. (1997) "High Frequency Data in Financial Markets: Issues and Applications" Journal of Empirical Finance, 4 (2) 73-114.

Jiang, G., Lo, I. and Verdelhan, A. (2007) "Why Do Bond Prices Jump? A Study of the US Treasury Market" paper presented at the Third Central Bank Workshop on Market Microstructure, Budapest, September 14-15 2007.

Jones, C.M., Kaul, G. and Lipson, M.L. (1994) "Transactions, Volume, and Volatility" The Review of Financial Studies, 7 (4) 631 – 51.

Kalimipalli, H. and Warga, A. (2002) "Bid-Ask Spread, Volatility and Volume in the Corporate Bond Market" The Journal of Fixed Income, 11 (4) 31 -

Karpoff, J.M. (1987) "The Relation Between Price Changes and Trading Volume: A Survey" The Journal of Financial and Quantitative Analysis, 22 (1) 109-126.

Kawaller, I.G., Koch, P.D. and Koch, T.W. (1987) "The Temporal Price Relationship Between S&P 500 Futures and the S&P 500 Index" The Journal of Finance, 42 (5) 1309-1329.

Kiymaz, H. and Berument, H. (2003) "The Day of the Week Effect on Stock Market Volatility and Volume: International evidence" Review of Financial Economics, 12 (4) 363 –

Kocagil , A.E. and Shachmurove, Y. (1998) "Return-Volume Dynamics in Futures Markets" Journal of Futures Markets, 18 (4) 399 – 426.

Lamoureaux, C.G. and Lastrapes, W.D. (1990) "Heteroskedasticity in Stock Return Data: Volume versus GARCH effects" Journal of Finance, 30 (1) 221-229.

Mizrach, B. and Neely, C. (2006a) "The Transition to Electronic Communications Networks in the Secondary Treasury Market", Federal Reserve Bank of St Louis *Review*, 88 (6), 527-41.

Mizrach, B. and Neely, C. (2006b) "Price Discovery in the US Treasury market", Federal Reserve Bank of St Louis Working Paper 2005-070C.

Li, J. and Wu, C. (2006) "Daily Return Volatility, Bid-Ask Spreads, and Information Flow: Analyzing the Information Content of Volume" The Journal of Business, 79, (5) 2697 –

Mahieu, R. and Bauer, R. (1998) "A Bayesian Analysis of Stock Return Volatility and Trading Volume" Applied Financial Economics, 8 (6) 671 - 88

Stoll, H.R. and Whaley, R.E. (1990) "The Dynamics of Stock Index and Stock Index Futures Returns" The Journal of Financial and Quantitative Analysis, 25 (4) 441-468.

Xiaoqing, E.X., and Wu, C. (1999) "The intraday relation between return volatility, transactions, and volume" International Review of Economics & Finance, 8 (4) 375 –

Figure 1
10-year Treasury Bond and Futures Price

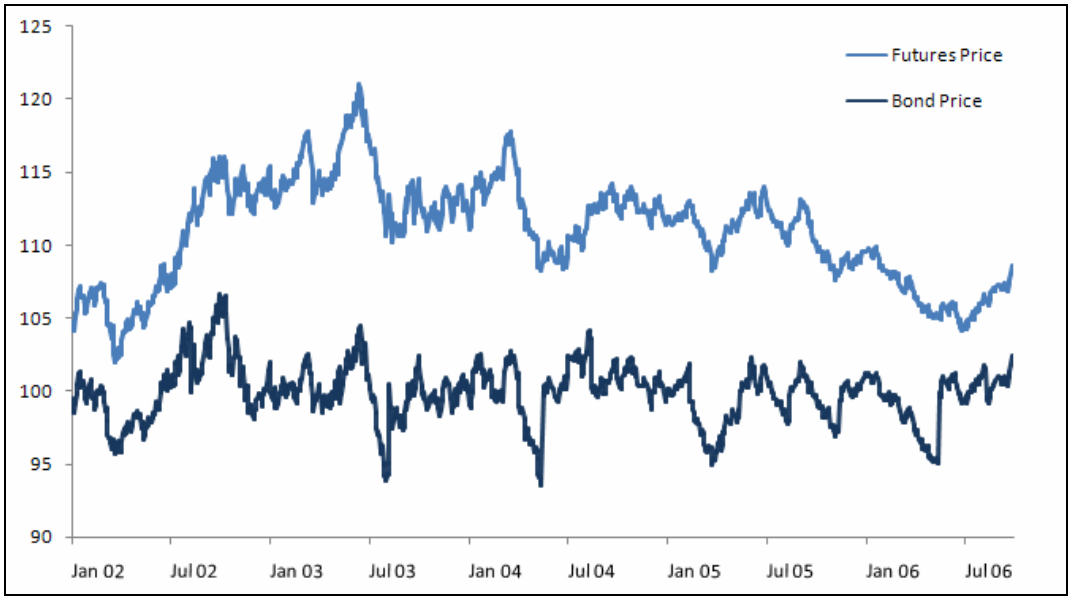

Table 1
US 10-year Treasury Bond and Futures Descriptive Statistics

This table summarises the one minute returns data (rescaled by a factor of 1,000) for a 10-year bond and its corresponding futures using the sample of 8:25 to 8:36 on days containing either a CPI, PPI or NFP news announcement and days containing none of the other announcements listed in the Appendix for the period January 2, 2002 – September 29, 2006.

	Bond Returns	Futures Returns
Mean	0.015085	0.015169
Median	0.000	0.000
Maximum	17.025	10.331
Minimum	-17.869	-20.540
Std. Dev.	0.835	0.755
Skewness	-0.171	-3.481
Kurtosis	140.327	188.024
Jarque-Bera P-value	0.000	0.000

Table 2
Dynamics of Bond Price Volatility, Trading Volume, and the Number of Trades across One-Minute Intervals, 2002-2006

	8:25-8:26	8:26-8:27	8:27-8:28	8:28-8:29	8:29-8:30	8:30-8:31	8:31-8:32	8:32-8:33	8:33-8:34	8:34-8:35	8:35-8:36
					Panel A: Price Volatility						
All	0.184	0.213	0.209	0.242	0.277	1.315	0.930	0.530	0.356	0.321	0.290
Announcement Day	0.182	0.333	0.328	0.462	0.542	2.910	2.055	1.134	0.650	0.534	0.460
Nonannouncement Day	0.222	0.210	0.213	0.209	0.205	0.223	0.248	0.232	0.231	0.232	0.194
Standard Deviation Ratio	0.820	1.587	1.540	2.211	2.641	13.043	8.298	4.876	2.821	2.306	2.366
F-test p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					Panel B: Trading Volume						
All	36.294	36.726	38.576	37.884	35.939	75.003	83.000	75.477	71.340	71.121	67.102
Announcement Day	46.353	46.545	48.521	48.717	41.762	128.633	172.237	147.692	149.053	150.112	133.834
Nonannouncement Day	31.028	34.731	31.556	31.853	30.837	33.052	36.221	35.291	34.754	35.601	32.575
Difference in Means	15.325	11.813	16.965	16.864	10.925	95.581	136.016	112.402	114.299	114.511	101.260
t-statistic p-value	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					Panel C: Number of Trades						
All	9	9	9	9	9	18	18	17	16	16	16
Announcement Day	10	10	10	11	9	31	34	31	30	31	28
Nonannouncement Day	8	8	7	8	7	7	8	9	8	8	7
Difference in Means	3	2	3	3	2	24	25	22	22	23	21
t-statistic p-value	0.000	0.037	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Note: One-minute log price change standard deviations, trading volume means and number of trades for announcement and non-announcement days for bond prices. The announcement days are those on which CPI, PPI or NFP were announced. Non-announcement days are those on which none of the scheduled macroeconomic news listed in the Appendix were announced. Statistical tests of differences in means for volumes and number of trades report the p-values from a t-test. For the price volatility the p-value is that of an F-test for difference in variances conducted using the Brown-Forsythe modification of the Levene F-test.

Table 3

Dynamics of Bond Price Volatility, Trading Volume, and the Bid-Ask Spread by One-Minute Intervals, Year by Year, No News

	8:25-8:26	8:26-8:27	8:27-8:28	8:28-8:29	8:29-8:30	8:30-8:31	8:31-8:32	8:32-8:33	8:33-8:34	8:34-8:35	8:35-8:36
					Panel A: Price Volatility						
2002	0.191	0.211	0.226	0.244	0.224	0.270	0.308	0.248	0.232	0.266	0.202
2003	0.276	0.236	0.213	0.220	0.200	0.207	0.242	0.257	0.258	0.223	0.235
2004	0.115	0.150	0.188	0.082	0.166	0.182	0.166	0.181	0.276	0.198	0.125
2005	0.216	0.215	0.198	0.123	0.226	0.156	0.115	0.128	0.097	0.156	0.128
2006	0.174	0.157	0.172	0.147	0.114	0.119	0.122	0.171	0.144	0.172	0.075
					Panel B: Trading Volume						
2002	27.761	26.662	28.262	26.561	28.164	32.939	33.338	31.439	32.031	35.185	32.710
2003	36.097	38.774	34.097	37.049	38.814	34.220	43.550	39.161	39.387	39.500	34.032
2004	25.588	31.500	29.444	32.579	24.111	24.000	32.167	32.278	34.625	28.833	35.833
2005	28.500	39.063	31.278	37.412	23.875	37.294	32.722	31.500	25.938	24.688	31.556
2006	34.308	57.167	38.750	26.429	25.917	37.364	25.636	45.417	37.077	42.417	22.643
					Panel C: Number of Trades						
2002	6	6	6	6	6	7	7	7	7	7	7
2003	8	8	7	8	8	7	9	9	9	8	8
2004	7	6	7	8	6	6	7	8	8	8	7
2005	9	8	9	9	8	10	11	10	8	8	9
2006	14	21	12	11	11	12	9	13	15	16	7

Table 4

Dynamics of Bond Price Volatility, Trading Volume, and the Bid-Ask Spread by One-Minute Intervals, Year by Year, News

	8:25-8:26	8:26-8:27	8:27-8:28	8:28-8:29	8:29-8:30	8:30-8:31	8:31-8:32	8:32-8:33	8:33-8:34	8:34-8:35	8:35-8:36
					Panel A: Price Volatility						
2002	0.180	0.189	0.162	0.178	0.238	1.755	2.175	1.962	0.534	0.435	0.384
2003	0.226	0.278	0.562	0.239	0.244	2.193	1.166	0.854	0.604	0.668	0.512
2004	0.168	0.622	0.366	0.939	0.696	4.866	3.618	1.050	0.868	0.521	0.484
2005	0.164	0.131	0.170	0.163	0.510	2.854	0.967	0.666	0.618	0.498	0.574
2006	0.149	0.114	0.119	0.159	0.842	1.353	0.561	0.451	0.554	0.525	0.222
					Panel B: Trading Volume						
2002	33.882	28.824	38.029	31.000	30.286	49.571	93.286	75.657	81.571	89.371	75.914
2003	42.472	46.111	49.250	50.412	37.000	57.833	134.500	121.833	121.333	86.639	101.250
2004	58.257	68.200	63.486	53.714	58.057	108.771	203.543	199.371	190.571	214.343	192.429
2005	44.639	48.694	48.722	53.444	40.556	153.667	189.694	152.389	164.250	152.167	143.972
2006	54.385	38.192	41.481	57.077	43.296	317.889	261.037	202.296	199.407	227.481	162.889
					Panel C: Number of Trades						
2002	7	6	8	7	6	7	12	12	13	13	11
2003	8	8	10	10	8	9	17	19	18	15	16
2004	11	13	12	11	11	16	26	27	27	30	26
2005	12	10	12	13	10	41	44	39	38	36	39
2006	15	12	11	16	11	100	79	65	64	73	54

Table 5
Dynamics of Futures Price Volatility, Trading Volume, and the Number of Trades across One-Minute Intervals, 2002-2006

	8:25-8:26	8:26-8:27	8:27-8:28	8:28-8:29	8:29-8:30	8:30-8:31	8:31-8:32	8:32-8:33	8:33-8:34	8:34-8:35	8:35-8:36
					Panel A: Price Volatility						
All	0.158	0.211	0.180	0.249	0.640	1.302	0.429	0.392	0.309	0.301	0.287
Announcement Day	0.165	0.227	0.232	0.488	1.662	3.089	0.881	0.748	0.570	0.548	0.516
Nonannouncement Day	0.194	0.177	0.198	0.263	0.223	0.257	0.248	0.201	0.217	0.215	0.180
Standard Deviation Ratio	0.851	1.283	1.174	1.854	7.449	12.023	3.555	3.712	2.622	2.544	2.864
F-test p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					Panel B: Trading Volume						
All	1358.405	1228.516	1068.702	1175.414	1214.585	4896.810	3362.515	2828.111	2736.789	2584.333	2449.198
Announcement Day	1215.396	1193.348	1078.275	1180.791	1734.154	10219.549	7280.445	6081.417	5646.566	5399.221	4974.388
Nonannouncement Day	985.686	1013.157	906.057	871.205	945.323	959.231	1016.771	1060.487	1045.522	987.058	998.761
Difference in Means	229.710	180.191	172.218	309.586	788.832	9260.318	6263.675	5020.929	4601.044	4412.163	3975.627
t-statistic p-value	0.074	0.160	0.125	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					Panel C: Number of Trades						
All	26	26	26	27	33	129	75	62	58	54	52
Announcement Day	31	31	34	40	62	329	186	152	132	122	117
Nonannouncement Day	20	22	21	19	20	22	20	23	23	21	20
Difference in Means	11	9	13	20	42	307	166	129	109	101	97
t-statistic p-value	0.000	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: One-minute log price change standard deviations, trading volume means and number of trades for announcement and non-announcement days for bond prices. The announcement days are those on which CPI, PPI or NFP were announced. Non-announcement days are those on which none of the scheduled macroeconomic news listed in the Appendix C announced. Statistical tests of differences in means for volumes and number of trades report the p-values from a t-test. For the price volatility the p-value is that of an F-test for difference in variances conducted using the Brown-Forsythe modification of the Levene F-test.

Table 6

Dynamics of Price Futures Volatility, Trading Volume, and the Number of Trades by One-Minute Intervals, Year by Year, No News

	8:25-8:26	8:26-8:27	8:27-8:27	8:27-8:29	8:29-8:30	8:30-8:31	8:31-8:32	8:32-8:33	8:33-8:34	8:34-8:35	8:35-8:36
					Panel A: Price Volatility						
2002	0.208	0.160	0.168	0.215	0.199	0.349	0.346	0.212	0.218	0.249	0.185
2003	0.207	0.196	0.207	0.364	0.290	0.201	0.195	0.234	0.237	0.208	0.224
2004	0.176	0.139	0.170	0.108	0.122	0.204	0.155	0.176	0.256	0.167	0.111
2005	0.144	0.206	0.185	0.184	0.196	0.113	0.138	0.106	0.145	0.223	0.116
2006	0.146	0.182	0.282	0.094	0.140	0.128	0.114	0.156	0.162	0.127	0.090
					Panel B: Trading Volume						
2002	505.482	516.170	545.036	561.018	476.714	588.893	569.696	674.255	625.333	576.947	577.321
2003	904.038	1012.547	999.569	950.302	831.564	979.830	1145.434	1077.019	1083.132	884.192	1078.765
2004	1115.500	1429.625	1264.706	1057.750	1373.063	1184.813	1463.941	1764.765	2223.111	1497.500	1088.118
2005	1661.467	1357.067	1116.294	944.333	1935.733	1474.667	1485.625	1131.563	865.938	1005.667	1244.200
2006	2324.643	1922.563	1267.125	1498.333	1620.250	1478.375	1224.333	1515.063	1193.875	2339.000	1893.750
					Panel C: Number of Trades						
2002	12	12	12	13	13	13	13	14	13	12	12
2003	19	20	21	19	17	19	21	21	20	19	20
2004	24	35	42	32	37	34	35	44	56	36	35
2005	35	35	24	20	31	32	24	30	23	18	28
2006	36	36	24	30	28	37	24	33	25	53	27

Table 7

Dynamics of Futures Price Volatility, Trading Volume, and the Number of Trades by One-Minute Intervals, Year by Year, News

	8:25-8:26	8:26-8:27	8:27-8:27	8:27-8:29	8:29-8:30	8:30-8:31	8:31-8:32	8:32-8:33	8:33-8:34	8:34-8:35	8:35-8:36
					Panel A: Price Volatility						
2002	0.136	0.168	0.174	0.162	0.418	1.628	0.597	0.612	0.540	0.428	0.303
2003	0.240	0.335	0.381	0.283	0.866	2.880	0.738	0.721	0.558	0.656	0.764
2004	0.148	0.267	0.233	0.978	2.914	5.172	1.401	1.098	0.657	0.671	0.621
2005	0.129	0.178	0.139	0.189	1.438	2.316	0.660	0.671	0.580	0.446	0.420
2006	0.148	0.098	0.116	0.079	0.865	1.373	0.426	0.389	0.499	0.444	0.236
					Panel B: Trading Volume						
2002	547.958	441.174	405.920	332.556	373.957	1287.414	1470.800	1535.962	1280.320	1080.731	1079.000
2003	1075.385	940.231	870.143	823.231	976.259	3710.733	3802.750	3268.857	2992.704	3330.760	3005.333
2004	1539.345	1405.679	1482.500	1579.065	2367.688	12713.286	9862.788	7877.625	6772.029	6413.000	6187.125
2005	1345.344	1205.543	1120.559	1485.156	2216.219	15678.333	9660.059	8306.000	7614.265	7194.563	7057.061
2006	1480.870	1954.609	1507.870	1620.478	2463.636	17407.077	10222.462	8759.435	8935.391	8532.826	6929.545
					Panel C: Number of Trades						
2002	13	12	11	11	12	20	24	23	22	20	19
2003	23	21	19	21	21	41	45	41	41	42	39
2004	59	54	58	79	108	564	328	264	211	194	202
2005	31	31	32	43	74	540	270	219	187	174	161
2006	25	31	52	37	79	419	205	175	158	147	133

Table 8
Granger Causality Tests for Bond Price and Futures Returns

This table presents the estimated regression results for a Granger test of causality (Equation 1) from the futures market to the bond market (Panel A) and the bond market to the futures market (Panel B) for the sample of news and non-news days. The formal Granger test of the null of no causality is presented at the bottom of the table.

	Panel A		Panel B	
Dependent Variable	$R_{B,t,a}$	t-stat	$R_{F,t,a}$	t-stat
α_0	0.0019	0.24	0.0241	1.36
β_1	-0.5672	34.02	-0.0212	0.79
β_2	-0.3481	18.39	0.0542	1.76
β_3	-0.2429	12.58	0.0071	0.23
β_4	-0.1729	9.47	-0.0571	1.93
β_5	-0.0583	4.18	-0.0072	0.32
χ_1	0.7778	50.61	-0.0111	0.45
χ_2	0.5095	25.29	-0.0055	0.17
χ_3	0.3129	14.65	-0.0823	2.37
χ_4	0.2357	11.09	0.0239	0.69
χ_5	0.1284	6.84	0.0076	0.25
R^2		0.31		0.01
Granger Test - F-statistic		518.802		5.095
- P-value		0.000		0.001

Note: absolute values of t-statistics reported

Table 9
Lead-lag Relationship for US 10-year Treasury Bond and Futures Returns

This table presents the estimated results for regression equation (2) and (3) for the sample of news and non-news days. In Panel A (C), the bond (futures) market returns are regressed against the 5 period leaded and lagged futures (bond) market returns. In Panel B (D), the regression equation is modified to include a multiplicative dummy variable that captures the change in the lead/lag relationship on news days. Wald Tests of coefficient equality and p-values are presented in the final rows.

	Panel A		Panel B		Panel C		Panel D	
Dependent Variable	$R_{B,t,a}$	t-stat	$R_{B,t,a}$	t-stat	$R_{F,t,a}$	t-stat	$R_{F,t,a}$	t-stat
ω_0	-0.0002	0.02	-0.0002	0.02	0.0030	0.34	0.0030	0.33
ϕ_{-5}	0.0131	0.93	-0.0114	0.16	-0.0007	0.05	-0.0073	0.12
ϕ_{-4}	-0.0022	0.16	0.0297	0.41	-0.0196	1.70	-0.0095	0.16
ϕ_{-3}	0.0247	1.84	-0.0224	0.31	-0.0099	0.89	0.0231	0.39
ϕ_{-2}	0.0354	2.66	0.0620	0.87	0.0248	2.27	-0.0109	0.18
ϕ_{-1}	0.4918	37.26	0.3209	4.52	-0.0255	2.35	0.0491	0.84
ϕ_0	0.5686	43.34	0.5527	7.59	0.4575	42.33	0.4232	7.14
ϕ_1	-0.0318	2.44	0.0888	1.21	0.3869	35.97	0.2527	4.23
ϕ_2	0.0408	3.15	-0.0186	0.26	0.0321	2.99	0.0342	0.57
ϕ_3	0.0047	0.36	0.0097	0.13	0.0029	0.27	-0.0050	0.08
ϕ_4	-0.0400	3.09	-0.0175	0.24	-0.0066	0.61	0.0151	0.25
ϕ_5	0.0080	0.57	0.0056	0.08	0.0165	1.53	-0.0026	0.04
γ_{-5}			0.0257	0.34			0.0065	0.11
γ_{-4}			-0.0330	0.45			-0.0101	0.17
γ_{-3}			0.0490	0.66			-0.0342	0.56
γ_{-2}			-0.0281	0.39			0.0373	0.62
γ_{-1}			0.1771	2.45			-0.0772	1.30
γ_0			0.0164	0.22			0.0357	0.59
γ_1			-0.1245	1.67			0.1385	2.28
γ_2			0.0619	0.85			-0.0021	0.03
γ_3			-0.0052	0.07			0.0083	0.14
γ_4			-0.0234	0.32			-0.0223	0.37
γ_5			0.0023	0.03			0.0201	0.33
R^2		0.45		0.45		0.44		0.44

Wald Tests	F-stat	p-value	F-stat	p-value	F-stat	p-value	F-stat	p-value
$\phi_{-1} + \phi_{-2} + \phi_{-3} + \phi_{-4} + \phi_{-5} = 0$	279.840	0.000	4.206	0.000	2.938	0.000	0.201	0.961
$\phi_{-1} = \phi_{-2} = \phi_{-3} = \phi_{-4} = \phi_{-5} = 0$	322.516	0.000	5.279	0.021	1.367	0.242	0.1175	0.731
$\phi_{-1}\gamma_{-1} = \phi_{-2}\gamma_{-2} = \phi_{-3}\gamma_{-3} = \phi_{-4}\gamma_{-4} = \phi_{-5}\gamma_{-5} = 0$	-	-	276.831	0.000	-	-	3.224	0.006
$\phi_{-1} + \phi_{-2} + \phi_{-3} + \phi_{-4} + \phi_{-5} = \phi_{-1}\gamma_{-1} + \phi_{-2}\gamma_{-2} + \phi_{-3}\gamma_{-3} + \phi_{-4}\gamma_{-4} + \phi_{-5}\gamma_{-5}$	-	-	3.624	0.057	-	-	0.138	0.710

Note: absolute values of t-statistics reported

Appendix
List of US macroeconomic announcements available from Bloomberg

Announcement	Source	Frequency	Time
Federal Funds Rate (target)	Federal Reserve	8 p.a.	2.15pm
Gross Domestic Product Annualised	Bureau of Eco. Analysis	Quarterly	8.30am
Producer Price Index	Bureau of Labor Stats.	Monthly	8.30am
Nonfarm Payrolls	Bureau of Labor Stats.	Monthly	8.30am
Unemployment Rate	Bureau of Labor Stats.	Monthly	8.30am
Retail Sales	U.S. Census Bureau	Monthly	8.30am
Trade Balance	U.S. Census Bureau	Monthly	8.30am
Consumer Credit	Federal Reserve	Monthly	3.00pm
Factors Affecting Reserve Balances	Federal Reserve	Weekly	4.30pm
Industrial Production	Federal Reserve	Monthly	9.15am
Capacity Utilization	Federal Reserve	Monthly	9.15am
Money Stock Measures	Federal Reserve	Weekly	4.30pm
Consumer Price Index	Bureau of Labor Stats.	Monthly	8.30am
Housing Starts	U.S. Dept. of Commerce	Monthly	8.30am
Building Permits	U.S. Dept. of Commerce	Monthly	8.30am
NAHB Housing Market Index	Nat. Assoc. of Home Builders	Monthly	1.00pm
Business Inventories	U.S. Census Bureau	Monthly	10.00am
ABC Consumer Confidence	ABC News Washington Post	Weekly	5.00pm
MBA Mortgage Applications	Mortgage Bankers Assoc.	Weekly	7.00am
Initial Jobless Claims	Department of Labor	Weekly	8.30am
Continuing Claims	Department of Labor	Weekly	8.30am
Leading Indicators	Conference Board	Monthly	10.00am
Philadelphia Fed	Philadelphia Fed. Reserve	Monthly	12.00pm
S&P/CS Composite 20 Home Price Index	Case-Shiller	Monthly	9.00am
ISM Manufacturing	Institute for Supply Management	Monthly	10.00am
ISM Prices Paid	Institute for Supply Management	Monthly	10.00am
Pending Home Sales MoM	National Assoc. of Realtors	Monthly	10.00am
Challenger Job Cuts	Challenger, Gray & Christmas	Monthly	7.30am
ADP Employment Change	Automatic Data Processing Inc.	Monthly	8.15am
Construction Spending MoM	U.S. Census Bureau	Monthly	10.00am
Factory Orders	U.S. Census Bureau	Monthly	10.00am
Total Vehicle Sales	Bloomberg Indices	Monthly	N/A
Domestic Vehicle Sales	Bloomberg Indices	Monthly	N/A
ISM Non-Manufacturing	Institute for Supply Management	Monthly	10.00am

Appendix (Con't)

Wholesale Industries	U.S. Census Bureau	Monthly	10.00am
Import Price Index MoM	Bureau of Labor Statistics	Monthly	8.30am
Monthly Budget Statement	U.S. Treasury	Monthly	2.00pm
Empire Manufacturing	Federal Reserve	Monthly	8.30am
Net Foreign Security Purchases	U.S. Treasury	Monthly	9.00am
University of Michigan Confidence	University of Michigan Research	Monthly	9.45am
Richmond Fed Manufacturing Index	Richmond Fed	Monthly	10.00am
Existing Home Sales	National Association of Realtors	Monthly	10.00am
Durable Goods Orders	U.S. Census Bureau	Monthly	8.30am
Help Wanted Index	Conference Board	Monthly	10.00am
New Home Sales	U.S. Census Bureau	Monthly	10.00am
Personal Income	Department of Commerce	Monthly	8.30am
Personal Spending	Bureau of Economic Analysis	Monthly	8.30am
Employment Cost Index	Bureau of Labor Statistics	Quarterly	8.30am