

Monetary Policy Tick-by-Tick*

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Abstract

Analysis of high-frequency data shows that Treasury note yields are highly volatile around FOMC announcements, even though the average effects of fed funds target rate surprises on such yields are fairly modest. We partially resolve this puzzle by showing that yield changes seem to depend not only on the surprises themselves, but on the shape of the yield curve at the time of announcement. We also show that the reaction of yields to FOMC announcements is sluggish, but that much of this sluggishness can be attributed to the few inter-meeting moves. Market liquidity around FOMC announcements behaves in a manner generally consistent with that found for other announcements, although the richness of FOMC announcement release practices induces differences in the market-adjustment process.

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Résumé

L'analyse de données de haute fréquence révèle que les rendements des bons du Trésor à court et à moyen terme sont très volatils aux alentours de l'annonce par la Réserve fédérale américaine du taux cible des fonds fédéraux, même si l'élément de surprise contenu dans l'annonce a en moyenne une incidence plutôt limitée sur ces rendements. Les auteurs résolvent partiellement cette contradiction en établissant que les variations des rendements dépendent non seulement de l'élément de surprise en soi, mais aussi de la forme de la courbe des rendements au moment de la divulgation du taux. Ils montrent par ailleurs que les rendements s'ajustent lentement aux annonces de la Réserve fédérale, mais que cette lenteur est due en grande partie aux quelques décisions prises en dehors du calendrier officiel des réunions. En règle générale, la liquidité du marché aux environs de ces annonces évolue comme lors de la publication d'autres nouvelles, bien que la richesse qualitative des communiqués de la Réserve fédérale donne lieu à un processus d'ajustement différent du marché.

1. Introduction

This paper uses high-frequency data to assess the effects of Federal Open Market Committee (FOMC) announcements on the U.S. Treasury securities market. A large macroeconomic literature tries to measure and interpret the reaction of yields to monetary policy shocks, but most of the studies use monthly data (Evans and Marshall, 2001), weekly data (Piazzesi, 2005), or daily data (Cook and Hahn, 1989, Kuttner, 2001, Cochrane and Piazzesi, 2002, and Demiralp and Jorda, 2004).¹ By using tick data, this paper seeks to more fully and precisely characterize the response of yields to monetary policy shocks.

The paper also seeks to more fully describe how yields adjust to FOMC announcements. The extant literature examines the speed of price response, return autocorrelation, trading activity, and bid-ask spreads for a variety of macroeconomic announcements, but not FOMC announcements (Ederington and Lee, 1993, 1995, Fleming and Remolona, 1999a, and Balduzzi, Elton and Green, 2001). The fact that FOMC announcements are sometimes unexpected and not released at a fixed time has likely inhibited their extensive study, but also introduces differences from other announcements which may affect market behavior.

Consistent with lower-frequency studies, we find that monetary policy surprises have significant effects on yields and that these effects decrease with

¹ An exception, closely related to this paper, is Gürkaynak, Sack, and Swanson (2005), who also use high-frequency data to assess the yield curve effects of FOMC announcements. Bollerslev, Cai, and Song (2000), Faust, Rogers, Wang, and Wright (2003), and Andersen, Bollerslev, Diebold, and Vega (2005) also use high-frequency Treasury data, but examine a wide variety of announcements and thus have more limited analyses and interpretations of FOMC announcements.

security maturity and are quite small for longer-term securities. Despite this, we find that longer-term yields are highly volatile around FOMC announcements. In fact, the average absolute yield change in the hour around announcement is higher for the two-year note than the three-month bill, even though the three-month bill reacts strongest to measured surprises. That is, Treasury note yields react strongly to FOMC announcements even though their average reaction to fed funds target rate surprises is modest.

Gürkaynak, Sack, and Swanson (GSS) (2005) also find strong reactions of longer-term yields to FOMC announcements in high-frequency data. They argue that two factors are required to explain the effects on yields, with one factor related to the current fed funds target rate and the second to the future path of policy. They assert that the second factor, which is particularly important in explaining longer-term yield changes, is closely associated with FOMC statements, first released after the February 1994 meeting and released after every meeting since May 1999.²

In contrast to GSS, we hypothesize that the slope of the yield curve is a useful conditioning variable to explain the reaction of longer-term yields. The idea is that the slope of the yield curve is correlated with market participants' time-varying concerns about inflation, so that when the curve is particularly steep or particularly flat (or inverted) policy surprises have less of an effect, or an inverse effect, on longer-term yields. Our regression results are supportive of our hypothesis:

² Kohn and Sack (2003) and Bernanke, Reinhart, and Sack (2004) make similar arguments.

Treasury note yields tend to react positively to surprises by themselves, but negatively to surprises interacted with our slope variable (defined as the absolute difference between the ten-year/three-month spread and its average over our sample).

Our analysis of the market-adjustment process suggests that the reaction to FOMC announcements is sluggish. Treasury bill yield changes in half-hour intervals that start after announcement are correlated with announcement surprises. Moreover, yield changes across the curve are positively autocorrelated in a number of half-hour intervals after announcement. In contrast, Treasury prices tend to react immediately to the surprises in other macroeconomic announcements and exhibit little autocorrelation after the first minute (Ederington and Lee, 1993, 1995, Fleming and Remolona, 1999a, and Balduzzi, Elton, and Green, 2001). Much of the sluggish response to FOMC announcements emanates from the few inter-meeting moves in our sample, that is, FOMC announcements that are largely unexpected by the market.

Other aspects of the adjustment process look quite similar to those found for other announcements by Fleming and Remolona (1999a) and Balduzzi, Elton, and Green (2001). Yield volatility thus peaks at announcement and remains higher than usual for about 1½ to 2½ hours. Trading volume peaks shortly after announcement and also remains higher than usual for 1½ to 2½ hours. Bid-ask spreads rise in anticipation of announcement, peak at announcement, and remain higher than usual for roughly 30 minutes to 2 hours. Quote prevalence falls in advance of

announcement, reaches a low point at announcement, and returns to normal 5 to 30 minutes after announcement.

While market behavior around FOMC announcements is generally similar to that of other announcements, the richness of FOMC announcement practices induces differences in the market-adjustment process. Not surprisingly, liquidity does not deteriorate in advance of announcements whose timing is largely a surprise (that is, the inter-meeting moves and some of the scheduled meeting announcements). For those announcements that are expected around the usual announcement time of roughly 2:15 pm (eastern time), variation in the precise announcement time is correlated with liquidity around the announcement. In particular, announcements that come out slightly later (earlier) are associated with longer (shorter) episodes of illiquidity and greater (lesser) illiquidity before the announcement. The results suggest that announcement time uncertainty decreases market liquidity around announcements.

The paper proceeds as follows. Section 2 explains our data for FOMC announcements, announcement times, monetary policy surprises, and Treasury market performance. Section 3 analyzes the macroeconomic effects of FOMC announcements on Treasury yields. Section 4 looks at the speed of price response to FOMC announcements. Section 5 examines liquidity around the announcements. Section 6 concludes.

2. Data

A. FOMC Announcements

Our sample period runs from January 1, 1994 to December 31, 2004. The beginning of 1994 is a natural starting point for our analysis as it was with the February 1994 meeting that the Fed started publicly announcing changes in its policy stance. Written statements have subsequently been released after every policy change and, since May 1999, after every meeting (policy change or not).³ The statements were at first imprecise about the precise policy directive for the fed funds target rate, but became increasingly more explicit.⁴ Moreover, the statements were expanded to include wording regarding the likelihood of a future increase or decrease in the target rate (referred to as the “policy bias”) in May 1999, which was then replaced by a “balance of risks” statement in February 2000.⁵

As the FOMC holds eight regularly scheduled meetings per year, our sample contains 88 announcements from these meetings. Our sample also contains five inter-meeting moves, from April 18, 1994, October 15, 1998, January 3, 2001, April 18, 2001, and September 17, 2001. The October 1998 change came in the midst of the

³ Until May 1999, the Fed disclosed that policy was unchanged by announcing that the meeting had ended and that there would be no further announcement.

⁴ The February 1994 statement says, “the Federal Open Market Committee had decided to increase slightly the degree of pressure on reserve positions. The action was expected to be associated with a small increase in short-term money-market rates.” The May 1994 statement says, “The Board approved an increase in the discount rate from 3 percent to 3¼ percent, effective immediately, and the Federal Open Market Committee (FOMC) agreed that this increase should be allowed to show through completely into interest rates in reserve markets.” The July 1995 statement says, “Today’s action will be reflected in a 25 basis point decline in the federal funds rate from 6 percent to about 5¾ percent.”

⁵ A January 2000 press release summarizes the changes in disclosure practices since 1994 (<http://www.federalreserve.gov/boarddocs/press/general/2000/20000119/>).

financial market turmoil following the Russian ruble devaluation and the near-collapse of Long-Term Capital Management. The September 17, 2001 change came in the wake of the September 11 attacks. Announcement dates and associated policy changes are listed in Appendix A.

B. FOMC Announcement Times

Critical to the high-frequency analysis of announcement effects is the use of accurate announcement times. Unlike macroeconomic announcements, which are released at precise, predetermined times, FOMC announcements, particularly inter-meeting ones, are made at a variety of times. Since September 1994, every announcement but one after a scheduled meeting has been released around 2:15 pm, but the exact timing has varied by up to several minutes.⁶ To collect announcement times, we search Bloomberg and Dow Jones for the time of the first story with information about a given rate change (or lack thereof) after a scheduled FOMC meeting or inter-meeting rate change.⁷ Announcement times are listed in Appendix A.⁸

⁶ On March 26, 1996, the meeting and announcement time were moved up in anticipation of Chairman Greenspan's Congressional testimony that afternoon. The fact that the announcement would be coming out early was disclosed in advance.

⁷ We do this by searching Dow Jones stories with "Federal Reserve" or "Fed" or "Federal Open Market Committee" or "FOMC" in the headline and Bloomberg stories in the "FED" news category (we also obtain the announcement times from Bloomberg's table of FOMC dates). Reassuringly, the earliest times from each source are identical for the last 31 announcements in our sample (in both cases, times are indicated to the minute). For earlier announcements, differences of a minute or more are not unusual (one reason this occurs is because Bloomberg "headlines" are not available historically; some culling of stories over time also seems to take place). When the earliest time differs between the two sources, we use the earlier of the two.

⁸ Our announcement times are quite close to those reported by GSS, who get their times from the Office of the Secretary of the Federal Reserve Board. In fact, the times are identical in 40 of 93

C. Monetary Policy Surprises

We use prices of fed funds futures contracts traded on the Chicago Board of Trade (CBOT) to identify policy surprises associated with FOMC announcements. Specifically, we employ the approach used by Kuttner (2001), Demiralp and Jorda (2004), GSS (2005), and Kuttner and Bernanke (2005). For most announcements, the surprise is calculated as the change in the current-month futures rate scaled up by a factor related to the number of days in the month affected by the change. For announcements within the last seven calendar days of the month, we use the change in the next month's futures contract.

One difference in implementation from earlier studies is that we assume some FOMC decisions affect fed funds rates the same day (whereas other studies assume that rates are not affected until the next day). FOMC policy decisions are effective immediately. Moreover, the decisions are announced before the fed funds market closes, often while significant market activity remains, and sometimes before Fed intervention time.⁹ In diverging from earlier studies, we take a conservative approach and assume that announcements made before Fed intervention time affect

cases (in both cases, times are reported to the minute), the average difference is 0.27 minutes (with our times earlier), the standard deviation of differences is 1.38 minutes, and the largest difference is 4 minutes. Many of the largest differences are from recent years, when Bloomberg and Dow Jones have identical times of 2:12 or 2:19, for example, but GSS times are 2:15. We suspect that GSS times within a few minutes of 2:15 are sometimes rounded to 2:15 (GSS report 70 instances of 2:15 announcements within our sample period, whereas we report 19 instances of 2:15 announcements).

⁹ Fed intervention time – the normal time the Fed's trading desk arranges temporary open market operations – was moved from about 11:30 am to 10:30 am January 2, 1997, and to 9:30 am April 5, 1999. For an intraday analysis of the fed funds market, see Bartolini, Gudell, Hilton, and Schwarz (2005).

rates that day whereas changes made after Fed intervention time do not affect rates until the next day.¹⁰

We calculate surprises for 30-minute, 60-minute, and daily intervals around announcement using tick and end-of-day data from the CBOT.¹¹ Thirty-minute (60-minute) surprises are calculated from the last trade at least five (10) minutes before announcement to the first trade at least 25 (50) minutes after announcement.¹² Daily surprises are calculated from the settlement price the day preceding announcement to the settlement price the day of announcement.¹³ Sixty-minute surprises are reported in Appendix B.

D. U.S. Treasury Securities

We analyze U.S. Treasury security tick data from GovPX, Inc. GovPX captures trading information from several brokers in the interdealer market and disseminates the information to subscribers in real time via the internet and financial service distributors. Reported data include the best bid and offer and the

¹⁰ Announcements were made before Fed intervention time on February 4, 1994, April 18, 1994, and September 17, 2001. The effective fed funds rate on these days was 3.19%, 3.70%, and 2.13% respectively, all much closer to the new than the old target rate.

¹¹ We combine open auction tick data for our full sample with electronic tick data since September 5, 2000. However, we only consider data between 8:20 am and 3:15 pm (eastern time) as the market can be less liquid outside of open auction trading hours. (The open auction market closes at 3 pm, but we set a 3:15 pm cutoff as open auction trades often have time stamps ten or so minutes after 3 pm.)

¹² If there is no trade at least five (10) minutes before announcement, we use the settlement price from the preceding day instead. If there is no trade at least 25 (50) minutes after announcement we generally use the settlement price for that day instead. For the October 15, 1998 announcement, made after the futures market closed, we use that day's settlement price as the pre-announcement price and the next day's opening price as the post-announcement price.

¹³ For the October 15, 1998 announcement, the daily surprise is calculated from the October 14 close to the October 16 open.

price and size of each trade. We utilize the history of these postings, provided by GovPX, which includes the time of each posting to the second. The same data are analyzed by Fleming and Remolona (1999a), Balduzzi, Elton, and Green (2001), Brandt and Kavajecz (2004), and others.

The GovPX data provide sufficient detail to effectively recreate what the market looked like in real time. In particular, if a quote is posted at time 0, not posted at time 2, and then posted again at time 5, one can infer that the quote was also posted at time 1, and that there was no quote posted at times 3 or 4. We process the data accordingly, on a minute-by-minute basis, recording the last quote in a given minute, and whether a quote was posted at the end of a minute. This innovative processing of the data allows us to assess liquidity around announcements in a distinct way from earlier studies.

The GovPX dataset covers our sample period quite well, especially for shorter-term securities. We have tick data around 92 of 93 announcements in our sample (the exception, the September 17, 2001 announcement, is excluded from our analysis).¹⁴ We also have tick data for 2656 of 2659 nonannouncement trading days.¹⁵ The tick data is sometimes sporadic, however, especially for longer-term

¹⁴ While we have tick data for September 17, 2001, it does not start until after announcement. Our “intraday” yield change for this announcement, reported in Appendix B (but excluded from our analysis), is calculated using the previous trading day’s close as the preannouncement yield.

¹⁵ The number of nonannouncement trading days equals the number of weekdays in our sample (2870) minus holidays (114), other nontrading days (4), and announcement days (93). The four nontrading days in our sample that were not scheduled holidays are April 17, 1994 (President Nixon’s funeral), September 11, 2001 (when trading stopped early in the day), September 12, 2001, and June 11, 2004 (President Reagan’s funeral). The trading days for which we are missing

securities in later years, as GovPX coverage of the interdealer market has declined.¹⁶ Also, GovPX stopped reporting aggregate volume information in April 2001, precluding the unique identification of trades since then.

The particular variables we examine are yield changes, trading volume, bid-ask spreads, and quote incidence.¹⁷ Yield changes are calculated using bid-ask mid-yields to mitigate problems associated with bid-ask bounce and illiquid trading conditions. Such changes are calculated from the last quote in an interval to the last in the next interval.¹⁸ Bid-ask spreads are measured using the last quote in a minute. Quote incidence (or the likelihood of a quote being posted) is based on whether a quote is posted at the end of minute. Trading volume is self explanatory.

We examine on-the-run Treasury securities from across the yield curve, including the three-month bill, six-month bill, two-year note, five-year note, and ten-year note. These are the five securities that were regularly issued over our entire

tick data are January 31, 1995 (the tick file stops at 2:45 am that day) and September 13-14, 2001. Tick data are partially missing for several other days.

¹⁶ Fleming (2001) reports that GovPX coverage of the interdealer market fell from 65% in 1997 to 42% in the first quarter of 2000. Boni and Leach (2002) show that this decline was concentrated among coupon securities.

¹⁷ Before constructing these variables, we clean the data by screening out quotes in which the bid-ask spread is wider than 10 basis points. Such quotes are likely to be often erroneous, and, when not erroneous, of reduced value in assessing the macroeconomic effects of announcements. We also identify extreme yield changes in our sample and delete a small number of “handle” errors whereby a price of 97 14/32 (for example) is mistakenly input as 98 14/32. Lastly, the algorithm used to identify trades from changes in aggregate trading volume is adapted to ensure that all trades are of positive quantities. For additional details on the format, cleaning, and processing of historical GovPX data, see Fleming (2001).

¹⁸ This sometimes results in missing observations (if no quote is posted in one of the intervals), especially for longer-term securities. In the next section only, we complement our GovPX tick data with end-of-day data from GovPX, the Board of Governors, and Bloomberg in order to examine the macroeconomic effects of all announcements (excluding September 17, 2001) and to compare announcement days to all nonannouncement days.

sample period. The four-week bill, one-year bill, three-year note, and thirty-year bond were only issued over part of our sample. Sixty-minute yield changes around FOMC announcements for our five securities are reported in Appendix B.

3. Macroeconomic Effects of FOMC Announcements

A. Effects of Surprises on Yields

We assess the macroeconomic effects of monetary policy surprises by regressing yield changes around FOMC announcements on our fed funds target rate surprises. The results, reported in Table 1, are fairly similar whether one examines hourly changes (Panel A) or daily changes (Panel B). The effects of surprises on yields decrease with maturity and are highly significant for short-term securities, but insignificant for longer-term securities. Looking at hourly changes, for example, 67% of policy surprises get transmitted into three-month yields (on average), but only 8% get transmitted into ten-year yields.

The results closely match those of other studies, such as Kuttner (2001), Demiralp and Jorda (2004), and GSS (2005), although the effects on longer-term yields are somewhat weaker here (perhaps due to differences in sample periods). The basic explanation for the decreasing effect of surprises further out the curve, noted by Cook and Hahn (1989) is that the fed funds target rate is mean reverting. Kuttner (2001) provides evidence that the less than one-for-one response of bill rates to surprises is attributable to the fact that surprises measured at high frequencies

have much to do with the timing of announcements rather than the actions themselves.

Two other points about the results are worth mentioning. First, the negative constant terms are consistent with the hypothesis that there is a risk premium around announcements for exposure to macroeconomic risk, as suggested by Jones, Lamont, and Lumsdaine (1998). Second, the R^2 s are very high for short-term securities, but quite modest for longer-term securities. The decreasing size of slope coefficients further out the curve does not therefore imply that longer-term securities react little to FOMC announcements, but that they react little to fed funds target rate surprises (on average).

B. Overall Effects of Announcements on Yields

We assess the effects of FOMC announcements on yields without regard to fed funds target rate surprises by examining absolute yield changes. Our results are reported in Table 2. Interestingly, the two-year note exhibits the largest yield changes in the hour around announcement (Panel A) and the reaction of longer-term notes is also quite strong. Matched sample t-tests indicate that the two-year note's response is significantly different from that of the three-month bill (at the 1% level) and ten-year note (at the 5% level). These results hold when controlling for typical hourly yield changes at the same time of day. Therefore, Treasury notes do seem to react quite strongly to FOMC announcements even though their average reaction to target rate surprises is modest.

Two of the more interesting market reactions are shown in Figure 1. On May 17, 1994 (Panel A), the FOMC raised the fed funds target rate by 50 basis points after 25 basis point increases in February, March, and April. Consistent with a positive target rate surprise (estimated as 11 basis points using a 60-minute window), the three-month bill rate settled several basis points higher. Longer-term rates plunged at announcement, however, with the five-year note falling 18 basis points in the hour around announcement. Press reports suggest that the response was attributable to reduced expectations of both inflation and further near-term policy tightening.¹⁹

On January 3, 2001 (Figure 1, Panel B), the FOMC unexpectedly cut the fed funds target rate by 50 basis points after having left rates unchanged since May 2000. Not only was this an inter-meeting move, but it represented a turning point after a series of rate increases in 1999 and 2000. Consistent with the large negative surprise (estimated as -36 basis points) short-term rates plunged. In contrast, long-term rates steadily climbed after announcement with the five-year yield rising 10 basis points in the hour around announcement. Press reports suggest that the response was

¹⁹ The *New York Times* reported, "the Fed's move was seen as a combative response to markets that for weeks have been demanding convincing evidence from the central bank that it was doing enough to rein in economic growth and dampen inflationary expectations." ("Credit Markets: Fed's Move Heartens Markets," Kenneth N. Gilpin, May 18, 1994, p. D1.) The *Financial Times* reported, "The moves helped the long end of the yield curve by easing any lingering concern over inflationary pressures. Shorter-term securities benefited as well, because the bold strike appeared to dispel the uncertainty engendered by the Fed's earlier gradualism. The decisiveness of yesterday's move suggested it was the last in the current series." ("Government Bonds: Treasuries Jump After Fed Raises Interest Rates," Frank McGurty, Conner Middelmann, and Graham Bowley, May 18, 1994, p. 32.)

attributable to decreased expectations of a recession and the associated strong equity market response.²⁰

Our results using daily data (Table 2, Panel B) are somewhat different. As in Panel A, average absolute yield changes around announcements are largest for intermediate-term notes. However, Treasury notes tend to be much more volatile on nonannouncement days, so that announcement/nonannouncement differences are more modest for the notes and statistically insignificant for the ten-year note. A likely explanation for the diverging results between the high-frequency and daily data is that other information affecting note yields is more commonly released on nonannouncement days.²¹

Our findings suggest significant benefits of using high-frequency data. Looking at daily data, one might not even notice that long-term yields react significantly to announcements, whereas such reactions are unambiguous when examining high-frequency data. Use of high-frequency data effectively controls for other information that affects the market without even having to specify what that

²⁰ *Reuters* reported, "U.S. Treasury prices, which had been rallying during the stock market's recent slump, tumbled on Wednesday as the Federal Reserve cooled fears of a recession with a dramatic half-point interest-rate cut that sent stocks soaring." ("U.S. Bond Markets: Fed Knocks Treasuries Back to Earth," Ellen Freilich, January 3, 2001).

²¹ Nearly all of our FOMC announcements (88 of 93) are made on Tuesday or Wednesday, but two of the most important macroeconomic announcements (the employment report and the producer price index) are typically released Thursday or Friday. In fact, Bollerslev, Cai, and Song (2000) report that 21 of the 25 largest absolute Treasury bond futures returns in their sample occurred right after a Thursday or Friday announcement. Fleming and Remolona (1999b) show that other announcements tend to affect longer-term yields more than short-term yields. It is also worth noting that some market-moving events are explicitly timed to avoid coinciding with FOMC announcements (in July 2003 the Treasury Department announced that it would adjust its note auction schedule to avoid coinciding with FOMC announcements, <http://www.treas.gov/press/releases/js581.htm>).

information is. Moreover, seeing that yields move at the time of announcement lends credence to the claim that the market is in fact reacting to the announcement and that the results are not spurious.

C. Conditioning Market Response on Shape of Yield Curve

The previous results show that long-term yields react significantly to FOMC announcements even though their average reaction to fed funds target rate surprises is quite modest. GSS (2005) argue that two factors are required to explain the effect of announcements on yields, with one factor related to the current fed funds target rate and the second to the future path of policy. They assert that this second factor is “not associated with the current federal funds rate decision of the FOMC but instead with statements that it releases” (p. 86).

While not disagreeing that statements may have important effects, we take a different approach and test whether the effects of target rate surprises on yields depend on market conditions. The conditioning variable we consider is the slope of the yield curve and, specifically, the ten-year/three-month spread.

The particular idea we consider is that the slope of the yield curve is correlated with market participants’ time-varying concerns about inflation. When the curve is particularly steep or particularly flat (or inverted), policy surprises have less of an effect, or an inverse effect, on long-term yields. When the curve is particularly steep, as it was May 17, 1994, there may be growing concerns that the Fed is falling behind the curve and perhaps not as committed to restraining inflation

as previously thought. In such an environment, a surprise increase may lower inflation expectations and thereby cause long-term yields to react little or even fall.

A similar but opposite story applies when the curve is particularly flat or inverted (as it was January 3, 2001). In such a case, concerns may be growing that the Fed is keeping the target rate too high for too long, increasing the probability of a “hard landing” and decreasing inflation expectations. A surprise decrease in such an environment may increase inflation expectations and thereby cause long-term yields to react little or even rise.

We test our hypothesis statistically by regressing yield changes around FOMC announcements on our surprise variable interacted with a slope variable, as well as the surprise variable itself. Our slope variable is defined as the absolute difference between the slope of the ten-year/three-month yield curve at the time of announcement and its 1.54% average over all announcements. Our slope variable ranges in value from 0.17% to 3.49%, with a mean of 1.61% and a standard deviation of 1.08%.²²

The results, presented in Table 3, are qualitatively similar whether one examines hourly changes (Panel A) or daily changes (Panel B). The coefficients on the surprise variables are larger than in Table 1, especially for notes, and are here significant for all securities. Moreover, the coefficients on the surprise/yield curve interaction variable are significantly negative for notes (and sometimes bills), and F-

²² These statistics are calculated with intraday data from 10 minutes before announcement (for the analysis of hourly changes). The statistics calculated with data from the previous day’s close (for the analysis of daily changes) are nearly the same.

tests (and likelihood ratio tests) indicate that the addition of the interaction term significantly improves model fit for notes. Therefore, when the slope of the yield curve is near its average level, yields tend to move in the same direction as surprises across the curve, but when the slope of the yield curve deviates far enough from its average, the predicted effect on longer-term yields is zero, or even negative.²³

Also note that while the R²s are higher in Table 3 than Table 1, they are still relative low for the notes. Conditioning on the slope of the yield curve helps explain the reaction of yields to FOMC announcements, but much of the reaction is left unexplained. Whether the announcement is a turning point seems to help explain the market's reaction, consistent with the findings of Demiralp and Jorda (2004).²⁴ The wording of FOMC statements may also be important, as argued by GSS (2005).

4. Speed of Response to FOMC Announcements

A. Price Adjustment Process

We proceed to examine how quickly prices react to FOMC announcements.

Other studies find that prices react almost instantaneously to surprises in other

²³ For the ten-year note, the predicted 60-minute yield change is about zero when the yield curve slope variable equals 1.32% ($1.32 = 0.479/0.362$).

²⁴ When we add a new variable to our model that allows the effects of surprises (both by themselves and interacted with our slope variable) to differ at turning points we find the coefficient positive and increasing monotonically with security maturity. The positive coefficient implies that whatever effect is otherwise predicted is amplified at turning points. The coefficient itself is significant at the 5% level for the two- and five-year notes (looking at hourly or daily changes). Moreover, likelihood ratio tests indicate that the additional term significantly improves model fit for all of the notes (looking at hourly or daily changes). Demiralp and Jorda (2004) find that yields react more strongly to surprises at turning points (and inter-meeting moves) in a model that does not condition on the slope of the yield curve.

macroeconomic announcements, and that there is little autocorrelation of returns after the first minute (Ederington and Lee, 1993, 1995, Fleming and Remolona, 1999a, and Balduzzi, Elton, and Green, 2001). It is possible, however, that the adjustment to FOMC announcements diverges from that of other announcements because of differences in the nature of the information released. FOMC statements, in particular, have a qualitative component that is absent from many other announcements. Moreover, the fact that some FOMC announcements are unexpected may induce a different response from announcements that are released at precise, known times.

One way we assess the speed of price response is by regressing yield changes over various 30-minute intervals around announcement on our fed funds target rate surprises (calculated over the 30 minutes around announcement). The results, presented in Table 4, show that the largest and most significant responses tend to occur in the interval including the announcement release (that is, the interval starting five minutes before and ending 25 minutes after announcement), as would be expected. Reassuringly, the coefficients are similar in magnitude, albeit somewhat smaller, than the coefficients reported in Table 1 based on hourly changes.

Coefficients for other intervals around announcement suggest a sluggish response to target rate surprises. Yield changes for intervals starting after announcement are significantly correlated with surprises, especially for bills. For the six-month bill, in particular, yield changes are significantly and positively

correlated with surprises in four of the five half-hour intervals starting after announcement. For the five- and ten-year notes, yield changes in the interval before announcement are significantly correlated with surprises.

To better understand these results and what might be driving them, we generate regression influence statistics proposed by Belsey, Kuh, and Welsch (1980). For the seven security-intervals after announcement with significant positive coefficients (at the 5% level or better), the most influential observation is October 15, 1998, January 3, 2001, or April 18, 2001. Interestingly, all three observations correspond to inter-meeting moves, and all three are identified by Bernanke and Kuttner (2005) as influential in their analysis relating surprises to equity returns. In fact, when we exclude inter-meeting moves from our analysis, none of the coefficients for any of the security-intervals after announcement is significant at the 5% level or better.

There are several reasons inter-meeting moves might be particularly important in explaining the market's sluggish response. First, inter-meeting target rate surprises tend to be larger, so they naturally have more influence in the regressions. Second, the announcements may be harder to interpret because they are rare, occur in relatively uncertain environments, and perhaps have a larger "signaling" component than other announcements. Lastly, the unexpected nature of such announcements may prolong the adjustment process because it takes longer for the information to diffuse.

For the five- and ten-year notes, November 6, 2002 is the most or second most influential observation contributing to the positive coefficient in the interval before announcement. Stronger-than-expected results from a ten-year auction that day were released just after 1 pm, causing yields to decline in advance of the FOMC announcement.²⁵ Excluding this observation decreases the magnitude and significance of the coefficients in the pre-announcement interval (although the five-year coefficient remains significant at the 5% level and the ten-year coefficient at the 10% level).

A second way we assess the speed of price response is by examining yield change autocorrelations around announcement. The results, presented in Table 5, suggest significant positive autocorrelation across securities in the hour after announcement so that positive (negative) yield changes in the half hour including the announcement tend to be followed by positive (negative) yield changes in the subsequent half hour. For the bills, yield changes around announcement are also positively correlated with yield changes even later after announcement.

Again, we identify the most influential observations contributing to the positive autocorrelation and find October 15, 1998, January 3, 2001, and April 18, 2001, as among the most influential. Other particularly influential observations are February 4, 1994, July 6, 1995, and June 30, 1999. These latter three observations were not inter-meeting moves, but were turning points. Rerunning the correlation

²⁵ "U.S. Credit Markets: U.S. Treasuries Rally on Auction," *The Wall Street Journal Europe*, November 7, 2002, p. M3.

analysis without inter-meeting moves decreases the significance of the results only slightly. However, excluding the six scheduled meeting turning points as well as the inter-meeting moves largely eliminates the significance.

Many of the same reasons given for the slow transmission of inter-meeting target rate surprises into yields could also be relevant at turning points and help explain the positive autocorrelation after announcement. Moreover, qualitative information uncorrelated with target rate surprises might take more time to process, perhaps explaining why Treasury note yield changes around announcement, but not target rate surprises, are correlated with subsequent yield changes. GSS (2005), in fact, find evidence of a sluggish response to their second factor and argue that it may reflect the time required to assimilate the information in FOMC statements.

Lastly, we ask whether a dealer might be able to profit by exploiting the apparently anomalous price behavior reported in Tables 4 and 5. We do this by assessing the profitability of buying (selling) a security whose price rises in the half-hour around announcement, and then selling (buying) the security one hour later.²⁶ Profits are computed under the unrealistic assumption that a dealer trades at the midpoint and under the realistic assumption that a dealer buys (sells) at the offer (bid).

²⁶ The initial trade is made at the quote 25 minutes after announcement and, if no quote is posted at that time, at the first quote posted within the next five minutes (no trade is made if the market is so illiquid that no quote is posted within the next five minutes). The position is closed out at the quote 85 minutes after announcement and, if no quote is posted at that time, at the first quote posted after that (so that all positions are closed out the same day).

The results, reported in Table 6, show that the potential profits of following a momentum-based trading strategy around FOMC announcements are largely eliminated by transaction costs. If a dealer could trade at the midpoint, expected profits would be significantly positive, consistent with the significant positive autocorrelation identified in Table 5. Buying at the offer and selling at the bid, however, produces profits that are insignificantly different from zero for most securities.

Part of the reason transaction costs dissipate profits so much is that bid-ask spreads are wider than usual after FOMC announcements (as shown later). At the same time, the magnitude of subsequent price changes after FOMC announcements is not all that large, even though it is larger than usual. As a result, the average yield pickup is only about a basis point in the case where a dealer could trade at the midpoint. Put another way, the correlation coefficients show that a large fraction of yield changes after announcement can be explained by the initial change, but the magnitude of what is being explained in terms of basis points is modest.

B. Volatility Persistence

Another way we assess the speed of response to FOMC announcements is to examine volatility persistence. Even if prices were to react immediately to surprises and returns exhibited no significant autocorrelation after announcement, volatility could persist for an extended period. In fact, Fleming and Remolona (1999) and Balduzzi, Elton, and Green (2001) find that volatility persists for at least an hour

after major announcements even though prices adjust immediately to surprises.

One interpretation is that investors have different views as to what an announcement means for prices depending on their analyses and customer order flows and that it takes time for these differing views to be reconciled.

Table 7 and Figure 2 compare average absolute yield changes around FOMC announcements to average absolute yield changes at the same time of day on nonannouncement days and indicate whether the differences are significantly different from zero. The results are fairly consistent across securities in showing that volatility jumps at announcement and then persists for 1½ to 2½ hours. Moreover, the basic pattern holds excluding inter-meeting moves and turning points (although the magnitudes are lower).

The results also show that volatility is somewhat higher for bills right before announcement, perhaps due to reduced liquidity at that time. Treasury note volatility is close to normal right before announcement, but somewhat lower in the hours preceding announcement. Jones, Lamont, and Lumsdaine (1998) find that return volatility is lower than usual (the day) before announcement and argue that such behavior is consistent with the “calm before the storm” effect often cited in the financial press.

5. Liquidity around FOMC Announcements

A. Trading Activity and Bid-Ask Spreads

We assess liquidity around FOMC announcements by examining trading volume, bid-ask spreads, and quote incidence. Table 8 and Figure 3 compare average trading volume in intervals around FOMC announcements to average volume at the same time of day on nonannouncement days and indicate whether the differences are significantly different from zero. The basic finding, observed for all securities, is that volume jumps at announcement, remains much higher than usual for about 45 minutes, and remains somewhat higher than usual for 1½ to 2½ hours. The pattern looks quite similar excluding inter-meeting moves and turning points.

Other studies report a similar finding for other macroeconomic announcements. Fleming and Remolona (1999) thus find that trading volume remains significantly elevated for about 90 minutes after consumer price index, employment, and producer price index announcements (examined together) while Balduzzi, Elton, and Green (2001) report that volume remains elevated for at least an hour after a number of announcements (examined separately). A common explanation, dating back to Beaver (1968), is that the high volume reflects a lack of consensus among market participants as to what the announcement means for prices.

Volume seems somewhat lower in the hours before announcement for notes, consistent with the “calm before the storm” effect discussed earlier. Moreover, volume is lower in the 5 to 10 minutes before announcement across all securities.

Lastly, there is a sharp decrease in volume on both announcement and nonannouncement days about 45 minutes after announcement. Recall that most announcements are made about 2:15 pm, so this decline occurs right around 3 pm, corresponding to the close of futures trading on the CBOT (as noted by Fleming, 1997). Cash market trading continues until about 5:30 pm, just more than three hours after most FOMC announcements.²⁷

Average bid-ask spreads are compared in the same manner as trading volume in Table 9 and Figure 4. Bid-ask spreads start to widen before announcement, peak at announcement, and remain wider than usual for roughly 30 minutes to 2 hours after announcement, depending on the security. Excluding inter-meeting moves and turning points, the pattern looks similar, although spreads seem to return to normal somewhat faster for the bills.

Fleming and Remolona (1999a) and Balduzzi, Elton, and Green (2001) also find spreads rising before announcement and peaking at announcement, and the latter study finds persistently wide spreads after announcement for the employment report. Before announcement, spreads are high because of the risk of taking on new positions before a large price change, and because quotes outstanding at the time of announcement risk getting picked off. After announcement, inventory risks remain high because of continued volatility and informational asymmetry may be higher

²⁷ The market typically closes early (e.g., 2 pm) before holidays. Early holiday closes are more prevalent on nonannouncement days and can explain some of the announcement/nonannouncement day differences.

than usual, perhaps because some dealers have information about their own customers' order flow.

Lastly, Figure 5 compares the incidence of quotes around announcements to their incidence at the same time of day on nonannouncement days. The incidence of posted quotes is typically near 100% for the bills and two-year note, implying that there is nearly always a quote posted among the brokers reporting to GovPX.²⁸ The incidence of quotes starts falling 10 to 15 minutes before announcement, reaches a trough of about 50% right before announcement, and then returns to normal 5 to 30 minutes after announcement. The pattern looks similar excluding inter-meeting moves and turning points.

The findings lend analytical support to the idea, noted by Fleming and Remolona (1999a, p. 1908), that dealers routinely withdraw their quotes before major announcements so that broker screens "go blank." As mentioned, the risk of taking on new positions before announcements is high because of the expected high volatility and because an outstanding quote at announcement could be picked off. In fact, these risks are often deemed so high before FOMC announcements that no dealer is willing to even post a quote.²⁹

²⁸ As GovPX reports the best bid and the best offer from contributing brokers, the bid and offer need not be posted by the same dealer or even the same broker. However, as noted earlier, quotes with particularly wide bid-ask spreads are dropped, increasing the incidence of missing quotes. Quotes are also occasionally missing because of missing data for part of a day or because the market was closed for part of a day (we control for instances of missing an entire day or of the market being closed the entire day).

²⁹ As noted, our analysis screens out particularly wide bid-ask spreads so one could more precisely interpret our results as showing that dealers are reluctant to post quotes with spreads narrower than 10 basis points. In practice, dealers tend to withdraw their quotes completely

A few other points about quote incidence are worth making. First, quote incidence is higher than usual after announcement for the bills and two-year note, consistent with the higher than usual trading volume at that time.³⁰ Second, the sharp decline in quote incidence towards the end of the event interval corresponds to the falloff in activity that occurs at the end of the trading day. Lastly, the relatively low incidence of quotes for the five- and ten-year notes is explained by GovPX's limited coverage of these securities (as mentioned earlier).

B. Announcement Timing and Liquidity

While market liquidity around FOMC announcements is generally similar to that of other announcements, the richness of FOMC announcement practices induces cross-sectional differences in the market-adjustment process. Most FOMC announcements are expected by the market around 2:15 pm, but inter-meeting moves largely surprise the market at various times. Moreover, some of the announcements associated with scheduled meetings have been unexpected for the most part because of the newness of the announcement policy and/or uncertainty about the timing of the announcements. When we restrict our analysis to announcements whose timing was a surprise, we find that liquidity does not deteriorate in advance of announcement, as would be expected.³¹

right before announcement rather than momentarily adjusting their quotes to prices that are unlikely to be traded upon anyway.

³⁰ As noted earlier, early holiday closes are more prevalent on nonannouncement days and can explain some of the announcement/nonannouncement day differences.

³¹ The "surprise" announcements are defined as the five inter-meeting moves, the four scheduled meeting announcements that did not come out right around 2:15 pm (including the

Even for those announcements that are expected around 2:15 pm, there is variation in the precise announcement time. Such variation might be expected to affect liquidity around announcements. We know that liquidity typically deteriorates in advance of announcements. If dealers do not know if an announcement will be made at 2:12 pm or 2:18 pm, for example, they might very well withdraw and/or widen quotes in advance of 2:12 pm on the chance that the announcement comes out then. If the announcement comes out later, the period of poor liquidity before the announcement may be extended.

We test this hypothesis three ways. First, we ask whether average bid-ask spreads before announcement are related to announcement times. We do this by regressing average bid-ask spreads for the 10 minutes before announcement on announcement time (in minutes) and a control variable (the average bid-ask spread in the three-hour period ending 15 minutes before announcement). If there is a longer period of illiquidity before later announcements, then one might expect the average spread before later announcements to be wider.

Second, we ask whether the incidence of quotes before announcement is related to announcement time. We do this by regressing the incidence of quotes in the 10 minutes before announcement on announcement time and a control variable (the incidence of quotes in the three-hour period ending 15 minutes before announcement). If there is a longer period of illiquidity before later announcements,

May 17, 1994 2:26 pm announcement) and the first scheduled meeting announcement that did come out around 2:15 pm (the March 22, 1994 2:20 pm announcement). The other 83 announcements, released between 2:11 and 2:20 pm, are assumed to have been expected around 2:15 pm.

then one might expect the incidence of quotes before later announcements to be lower. We employ a two-sided censored (Tobit) regression model since the incidence of quotes is bound between zero and one.

Lastly, we test whether the length of time without any quote around announcement is related to announcement time. We do this by regressing the length of time without a quote around announcement on announcement time and a control variable (the incidence of quotes in the three-hour period ending 15 minutes before announcement).³² If there is a longer period of illiquidity before later announcements, then one might expect the length of time without a quote around later announcements to be longer. We employ a one-sided censored (Tobit) regression model since the dependent variable is left-censored at one minute (recall that we convert our raw tick data into minute-by-minute data).

Our results, reported in Table 10, support the idea that announcement time uncertainty increases illiquidity around announcements. The bid-ask spread coefficient in our first model is positive for all securities, and significantly so for the six-month bill, implying that bid-ask spreads tend to be wider (narrower) before later (earlier) announcements. The six-month bill coefficient of 0.188 implies that each minute delay increases the average bid-ask spread before announcement by about 0.2 basis points.

³² We estimate the length of time by looking for the longest period of time without a quote in the interval starting 30 minutes before announcement and ending 30 minutes after announcement, requiring that the interval not start more than five minutes after announcement and not end more than five minutes before announcement. This methodology does not presume that our announcement times are exactly right (but that they are within a few minutes of being right).

The quote incidence coefficient in our second model is generally negative, and significantly so for the three-month bill and two-year note, indicating that the incidence of quotes tends to be lower (higher) before later (earlier) announcements. The coefficient of -0.102 for the three-month bill implies that each minute delay decreases the (uncensored) incidence of quotes by about 10 percentage points (e.g., from 80% to 70%).

Lastly, the length of time without a quote coefficient in our third model is generally positive, and significantly so for the three-month bill and two-year note, indicating that later (earlier) announcements are associated with longer (shorter) periods without a quote. The coefficient of 1.134 for the two-year note implies that each minute delay lengthens the (uncensored) interval over which there is no quote by about a minute.

While these results are supportive of the hypothesis that announcement time uncertainty decreases market liquidity around announcements, one might argue that the period of decreased liquidity affected by announcement timing is fairly small – a number of minutes. We are sympathetic to this argument, but also think the results illustrate a more general point about information and liquidity that is applicable to a wide range of events that are relevant to the market. The manner in which information is released matters and, in particular, releasing information at precise times known in advance can mitigate market disruption.

6. Conclusion

Our high-frequency analysis of the effects of FOMC announcements on the U.S. Treasury securities market uncovers several interesting results. First, long-term yields react strongly to FOMC announcements, even though the average effects of fed funds target rate surprises on such yields are modest. We argue that the response of long-term yields may depend on the environment in which FOMC announcements are made, and, in particular, on the slope of the yield curve. In fact, we find that target rate surprises have less of an effect, or an inverse effect, on long-term yields when the curve is particularly steep or particularly flat (or inverted).

Second, the market seems to react sluggishly to FOMC announcements. Treasury bill yield changes in intervals starting after announcement are correlated with announcement surprises and yield changes across the curve are positively autocorrelated after announcement. Much of the sluggishness comes from rate changes that occur outside of regularly scheduled meetings. As inter-meeting moves differ in several aspects from other announcements, including being relatively rare, it is not clear what factor explains the sluggishness.

Lastly, market liquidity around FOMC announcements behaves in a manner generally similar to that found for other announcements, although variation in FOMC announcement practices induce differences in the market-adjustment process. Not surprisingly, liquidity does not deteriorate in advance of announcements whose timing is largely a surprise. For those announcements that are expected around 2:15 pm, we find variation in the precise release time helps

explain variation in liquidity, with liquidity poorer around later announcements.

These results suggest that announcement time uncertainty decreases market liquidity around the announcements.

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Appendix A – FOMC Monetary Policy Announcements

Date	Time	Scheduled Meeting?	Fed Funds Target Rate Change	New Fed Funds Target Rate
February 4, 1994	11:05 AM	Yes	25 bp	3.25%
March 22, 1994	2:20 PM	Yes	25 bp	3.50%
April 18, 1994	10:06 AM	No	25 bp	3.75%
May 17, 1994	2:26 PM	Yes	50 bp	4.25%
July 6, 1994	2:18 PM	Yes	0 bp	
August 16, 1994	1:17 PM	Yes	50 bp	4.75%
September 27, 1994	2:18 PM	Yes	0 bp	
November 15, 1994	2:20 PM	Yes	75 bp	5.50%
December 20, 1994	2:17 PM	Yes	0 bp	
February 1, 1995	2:14 PM	Yes	50 bp	6.00%
March 28, 1995	2:13 PM	Yes	0 bp	
May 23, 1995	2:13 PM	Yes	0 bp	
July 6, 1995	2:15 PM	Yes	-25 bp	5.75%
August 22, 1995	2:13 PM	Yes	0 bp	
September 26, 1995	2:14 PM	Yes	0 bp	
November 15, 1995	2:16 PM	Yes	0 bp	
December 19, 1995	2:15 PM	Yes	-25 bp	5.50%
January 31, 1996	2:16 PM	Yes	-25 bp	5.25%
March 26, 1996	11:39 AM	Yes	0 bp	
May 21, 1996	2:16 PM	Yes	0 bp	
July 3, 1996	2:14 PM	Yes	0 bp	
August 20, 1996	2:17 PM	Yes	0 bp	
September 24, 1996	2:14 PM	Yes	0 bp	
November 13, 1996	2:17 PM	Yes	0 bp	
December 17, 1996	2:16 PM	Yes	0 bp	
February 5, 1997	2:13 PM	Yes	0 bp	
March 25, 1997	2:14 PM	Yes	25 bp	5.50%
May 20, 1997	2:15 PM	Yes	0 bp	
July 2, 1997	2:15 PM	Yes	0 bp	
August 19, 1997	2:15 PM	Yes	0 bp	
September 30, 1997	2:13 PM	Yes	0 bp	
November 12, 1997	2:12 PM	Yes	0 bp	
December 16, 1997	2:15 PM	Yes	0 bp	
February 4, 1998	2:12 PM	Yes	0 bp	
March 31, 1998	2:14 PM	Yes	0 bp	
May 19, 1998	2:13 PM	Yes	0 bp	
July 1, 1998	2:14 PM	Yes	0 bp	
August 18, 1998	2:12 PM	Yes	0 bp	
September 29, 1998	2:17 PM	Yes	-25 bp	5.25%
October 15, 1998	3:14 PM	No	-25 bp	5.00%
November 17, 1998	2:19 PM	Yes	-25 bp	4.75%
December 22, 1998	2:13 PM	Yes	0 bp	
February 3, 1999	2:12 PM	Yes	0 bp	
March 30, 1999	2:12 PM	Yes	0 bp	
May 18, 1999	2:11 PM	Yes	0 bp	
June 30, 1999	2:15 PM	Yes	25 bp	5.00%

August 24, 1999	2:14 PM	Yes	25 bp	5.25%
October 5, 1999	2:12 PM	Yes	0 bp	
November 16, 1999	2:16 PM	Yes	25 bp	5.50%
December 21, 1999	2:13 PM	Yes	0 bp	
February 2, 2000	2:14 PM	Yes	25 bp	5.75%
March 21, 2000	2:15 PM	Yes	25 bp	6.00%
May 16, 2000	2:13 PM	Yes	50 bp	6.50%
June 28, 2000	2:15 PM	Yes	0 bp	
August 22, 2000	2:14 PM	Yes	0 bp	
October 3, 2000	2:12 PM	Yes	0 bp	
November 15, 2000	2:12 PM	Yes	0 bp	
December 19, 2000	2:16 PM	Yes	0 bp	
January 3, 2001	1:13 PM	No	-50 bp	6.00%
January 31, 2001	2:15 PM	Yes	-50 bp	5.50%
March 20, 2001	2:13 PM	Yes	-50 bp	5.00%
April 18, 2001	10:54 AM	No	-50 bp	4.50%
May 15, 2001	2:15 PM	Yes	-50 bp	4.00%
June 27, 2001	2:12 PM	Yes	-25 bp	3.75%
August 21, 2001	2:13 PM	Yes	-25 bp	3.50%
September 17, 2001	8:20 AM	No	-50 bp	3.00%
October 2, 2001	2:15 PM	Yes	-50 bp	2.50%
November 6, 2001	2:20 PM	Yes	-50 bp	2.00%
December 11, 2001	2:14 PM	Yes	-25 bp	1.75%
January 30, 2002	2:16 PM	Yes	0 bp	
March 19, 2002	2:19 PM	Yes	0 bp	
May 7, 2002	2:14 PM	Yes	0 bp	
June 26, 2002	2:13 PM	Yes	0 bp	
August 13, 2002	2:14 PM	Yes	0 bp	
September 24, 2002	2:12 PM	Yes	0 bp	
November 6, 2002	2:14 PM	Yes	-50 bp	1.25%
December 10, 2002	2:13 PM	Yes	0 bp	
January 29, 2003	2:16 PM	Yes	0 bp	
March 18, 2003	2:15 PM	Yes	0 bp	
May 6, 2003	2:13 PM	Yes	0 bp	
June 25, 2003	2:16 PM	Yes	-25 bp	1.00%
August 12, 2003	2:15 PM	Yes	0 bp	
September 16, 2003	2:19 PM	Yes	0 bp	
October 28, 2003	2:14 PM	Yes	0 bp	
December 9, 2003	2:14 PM	Yes	0 bp	
January 28, 2004	2:14 PM	Yes	0 bp	
March 16, 2004	2:15 PM	Yes	0 bp	
May 4, 2004	2:16 PM	Yes	0 bp	
June 30, 2004	2:18 PM	Yes	25 bp	1.25%
August 10, 2004	2:15 PM	Yes	25 bp	1.50%
September 21, 2004	2:15 PM	Yes	25 bp	1.75%
November 10, 2004	2:15 PM	Yes	25 bp	2.00%
December 14, 2004	2:15 PM	Yes	25 bp	2.25%

Note: Announcement times are the earliest times a Bloomberg or Dow Jones headline or story appeared with information about a rate change (or lack thereof) after a scheduled FOMC meeting or inter-meeting rate change.

Appendix B –Monetary Policy Surprises and Yield Changes around FOMC Announcements

Date	Policy Surprise	Yield Change				
		3-month	6-month	2-year	5-year	10-year
February 4, 1994	15.7	14.2	12.1	16.5	13.3	7.8
March 22, 1994	0.0	-8.0	-7.4	-10.6	-12.2	-11.4
April 18, 1994	13.8	12.9	13.0	13.1	13.4	10.2
May 17, 1994	11.1	3.4	-6.1	-11.9	-18.0	-19.0
July 6, 1994	-3.7	-3.6	0.0	-1.3	-0.3	0.5
August 16, 1994	14.5	9.9	6.2	6.5	2.1	-0.7
September 27, 1994	-9.0	-9.8	-4.1	-1.6	1.9	2.0
November 15, 1994	12.0	7.8	7.8	9.9	6.4	2.8
December 20, 1994	-22.5	-7.3	-5.2	-0.9	0.5	0.9
February 1, 1995	7.3	8.1	7.9	10.7	9.3	7.2
March 28, 1995	0.0	1.1	1.1	1.8	2.2	2.5
May 23, 1995	0.0	0.0	0.3	-0.9	-0.7	-0.7
July 6, 1995	-9.9	-15.2	-22.6	-26.9	-25.3	-20.1
August 22, 1995	0.0	2.1	1.9	3.1	3.6	3.2
September 26, 1995	4.0	7.1	7.0	4.2	4.3	2.7
November 15, 1995	5.0	3.2	3.5	3.2	2.4	1.4
December 19, 1995	-6.5	-3.1	-5.6	-7.1	-8.5	-7.9
January 31, 1996	-3.0	-1.8	-3.3	-4.6	-3.4	-1.5
March 26, 1996	2.0	-0.6	1.1	2.4	1.9	0.9
May 21, 1996	0.0	1.0	1.6	3.1	2.7	2.6
July 3, 1996	-6.1	-4.2	-3.5	-3.8	-4.1	-3.4
August 20, 1996	-2.8	-1.6	0.3	0.0	0.3	0.6
September 24, 1996	-12.0	-12.8	-11.5	-7.4	-4.3	-1.9
November 13, 1996	0.0	-0.9	-0.6	-1.8	-2.1	-3.2
December 17, 1996	-1.1	-1.1	-1.1	-0.2	-0.9	-0.7
February 5, 1997	-3.0	-1.1	0.0	1.5	1.9	2.6
March 25, 1997	5.0	1.3	5.3	8.1	9.1	8.1
May 20, 1997	-9.9	-11.7	-10.0	-5.4	-3.8	-1.5
July 2, 1997	-1.6	-0.3	-0.5	-0.7	-1.4	-1.3
August 19, 1997	0.0	0.3	0.0	-0.2	0.3	0.5
September 30, 1997	0.0	-0.6	-1.4	-0.6	-0.6	-0.1
November 12, 1997	-5.0	-3.2	-3.0	-3.7	-3.0	-2.8
December 16, 1997	0.0	-1.3	-1.4	-1.8	-1.5	-1.2
February 4, 1998	0.6	-0.3	1.1	2.5	1.6	1.3
March 31, 1998	0.0	-1.9	-0.3	-0.9	-1.1	-0.6
May 19, 1998	-2.6	-0.9	-1.9	-1.8	-1.4	-0.9
July 1, 1998	0.0	0.3	0.8	0.9	1.0	1.2
August 18, 1998	0.0	-0.5	-0.6	0.0	0.4	0.0
September 29, 1998	6.0	-2.3	-0.2	2.1	-2.1	-2.8
October 15, 1998	-26.2	-16.6	-28.5	-25.2	-21.3	-17.1
November 17, 1998	-6.9	-1.3	-0.6	12.2	8.2	5.1
December 22, 1998	0.0	1.1	1.9	1.0	1.2	2.0
February 3, 1999	0.0	-0.5	0.6	2.3	3.6	4.2
March 30, 1999	0.0	-1.8	-2.4	-4.8	-4.5	-3.6
May 18, 1999	-1.2	0.3	3.2	11.2	11.2	8.4
June 30, 1999	-4.0	-10.4	-8.0	-18.4	-19.9	-14.6

August 24, 1999	3.5	0.8	-1.9	-3.1	-3.8	-3.3
October 5, 1999	-4.8	0.1	2.7	7.8	10.6	9.8
November 16, 1999	7.5	4.8	3.8	8.1	7.5	5.8
December 21, 1999	0.0	1.6	1.6	4.4	5.0	4.8
February 2, 2000	-5.9	-6.3	-2.5	2.6	2.9	2.1
March 21, 2000	-3.1	-2.4	-1.7	2.2	-0.2	-2.3
May 16, 2000	4.1	2.4	2.2	4.4	3.4	0.8
June 28, 2000	-2.5	-3.7	-0.8	-3.1	-2.7	-1.1
August 22, 2000	-1.7	0.0	0.0	0.7	-0.2	-0.4
October 3, 2000	-0.6	-0.5	0.0	3.2	3.4	2.2
November 15, 2000	-1.0	0.3	0.0	-0.9	-1.8	-2.5
December 19, 2000	6.5	0.3	0.0	0.9	-0.8	-0.3
January 3, 2001	-36.5	-23.5	-15.8	-1.1	10.1	22.1
January 31, 2001	3.5	1.6	-2.6	-4.0	0.0	-3.4
March 20, 2001	5.6	-0.5	-5.0	-10.0	-6.2	-4.3
April 18, 2001	-42.5	-25.6	-25.6	-28.8	-22.1	-10.3
May 15, 2001	-7.8	-4.4	-7.9	-8.0	-3.3	2.0
June 27, 2001	11.0	9.0	7.6	10.4	5.3	0.1
August 21, 2001	1.6	-1.1	-2.9	-7.1	-3.5	-0.7
September 17, 2001	-28.9	-4.2	1.2	4.5	7.0	4.9
October 2, 2001	-3.2	-5.7	-5.5	-4.7	-4.2	-3.9
November 6, 2001	-13.1	-15.9	-16.0	-13.0	-5.5	-0.3
December 11, 2001	0.0	-1.6	-1.8	-3.3	-3.7	-1.3
January 30, 2002	2.0	2.3	0.8	2.2	0.6	-2.3
March 19, 2002	-2.6	-3.4	-3.6	-4.7	-3.9	-4.8
May 7, 2002	0.6	-1.0	-1.1	-1.9	-2.0	-4.3
June 26, 2002	0.5	1.0	1.0	4.2	4.9	-7.5
August 13, 2002	3.4	-2.0	-4.7	-9.4	-6.3	-10.3
September 24, 2002	3.0	1.8	2.1	3.7	1.1	-5.0
November 6, 2002	-18.8	-16.7	-12.3	3.7	1.6	0.9
December 10, 2002	0.0	0.0	0.3	2.2	0.2	-0.8
January 29, 2003	0.5	1.3	1.8	3.7	2.8	4.4
March 18, 2003	2.4	1.3	1.1	1.7	1.0	6.7
May 6, 2003	3.1	-1.3	-4.9	-14.1	-16.6	-10.0
June 25, 2003	12.5	10.7	10.6	12.1	17.4	15.4
August 12, 2003	0.0	-0.5	-0.3	-6.3	4.8	7.3
September 16, 2003	0.0	0.3	-0.3	-0.8	-0.7	0.8
October 28, 2003	-0.5	-1.6	-2.1	-12.3	-14.9	-10.3
December 9, 2003	0.0	-0.3	0.3	7.5	9.7	8.4
January 28, 2004	0.3	2.0	3.3	18.0	18.6	14.4
March 16, 2004	0.0	-0.8	-1.5	-8.2	-11.3	-7.5
May 4, 2004	-1.1	-0.8	0.0	-0.3	5.7	6.6
June 30, 2004	-1.0	-2.3	-2.6	-8.1	-10.8	-10.5
August 10, 2004	1.5	0.0	2.8	7.2	7.4	5.0
September 21, 2004	0.0	-2.0	-1.5	-1.5	-2.1	-4.4
November 10, 2004	0.0	-0.6	0.0	-0.8	0.6	-0.7
December 14, 2004	-0.9	-2.3	-1.6	-1.8	-3.4	-5.4

Note: Yield changes and surprises are measures over the one-hour period starting 10 minutes before the announcement release.

Table 1 – Effects of Fed Funds Target Rate Surprises on Yields

Panel A: Hourly Data					
Security	Constant		Surprise		Adjusted R ²
3-month bill	-0.006**	(0.003)	0.666***	(0.044)	0.82
6-month bill	-0.007*	(0.004)	0.609***	(0.074)	0.66
2-year note	-0.002	(0.007)	0.483***	(0.130)	0.26
5-year note	-0.001	(0.008)	0.313**	(0.148)	0.11
10-year note	-0.003	(0.007)	0.083	(0.156)	0.00

Panel B: Daily Data					
Security	Constant		Surprise		Adjusted R ²
3-month bill	-0.021***	(0.005)	0.612***	(0.060)	0.57
6-month bill	-0.021***	(0.006)	0.592***	(0.084)	0.49
2-year note	-0.007	(0.008)	0.334**	(0.154)	0.11
5-year note	-0.008	(0.009)	0.170	(0.194)	0.02
10-year note	-0.010	(0.008)	0.008	(0.173)	-0.01

Notes: The table reports results from regressions of yield changes on fed funds target rate surprises (both measured in percent). Yield changes and surprises are measured over the one-hour period starting 10 minutes before the announcement release in Panel A and over the day of the announcement in Panel B. Coefficients are reported with heteroskedasticity-consistent (White) standard errors in parentheses. One, two, and three asterisks denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 2 – Effects of FOMC Announcements on Absolute Yields

Panel A: Hourly Data				
Security	Announcement	Nonannouncement	Difference	Standard Error
3-month bill	3.97	0.64	3.33***	0.55
6-month bill	4.05	0.64	3.41***	0.57
2-year note	5.70	1.16	4.54***	0.61
5-year note	5.39	1.26	4.13***	0.60
10-year note	4.69	1.24	3.45***	0.51

Panel B: Daily Data				
Security	Announcement	Nonannouncement	Difference	Standard Error
3-month bill	5.05	2.59	2.46***	0.57
6-month bill	5.63	2.64	3.00***	0.56
2-year note	6.38	4.66	1.72***	0.58
5-year note	6.39	5.05	1.35**	0.59
10-year note	5.49	4.77	0.72	0.52

Notes: The table reports average absolute yield changes around announcements, average absolute yield changes on nonannouncement days for the same interval, the differences between the two sets of changes, and the standard errors of the differences (all measured in basis points). Yield changes are measured over the one-hour period starting 10 minutes before the announcement release in Panel A and over the day of the announcement in Panel B. One, two, and three asterisks denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 3 – Explaining Yield Changes around FOMC Announcements

Panel A: Hourly Data							
Security	Constant		Surprise		Surprise * Spread		Adjusted R ²
3-month bill	-0.006**	(0.003)	0.685***	(0.083)	-0.017	(0.041)	0.82
6-month bill	-0.007*	(0.004)	0.721***	(0.101)	-0.102**	(0.049)	0.67
2-year note	-0.001	(0.007)	0.791***	(0.118)	-0.282***	(0.054)	0.31
5-year note	0.000	(0.007)	0.683***	(0.116)	-0.338***	(0.068)	0.19
10-year note	-0.002	(0.007)	0.479***	(0.119)	-0.362***	(0.092)	0.13

Panel B: Daily Data							
Security	Constant		Surprise		Surprise * Spread		Adjusted R ²
3-month bill	-0.020***	(0.005)	0.751***	(0.124)	-0.123*	(0.067)	0.58
6-month bill	-0.021***	(0.006)	0.732***	(0.150)	-0.124*	(0.070)	0.49
2-year note	-0.006	(0.008)	0.701***	(0.147)	-0.326***	(0.078)	0.17
5-year note	-0.006	(0.009)	0.655***	(0.165)	-0.430***	(0.099)	0.13
10-year note	-0.009	(0.008)	0.431***	(0.150)	-0.375***	(0.094)	0.10

Notes: The table reports results from regressions of yield changes on fed funds target rate surprises and fed funds target rate surprises interacted with a yield curve spread variable (all measured in percent). The spread variable is defined as the absolute difference between the 10-year/3-month spread before announcement and its average over all announcements. Yield changes and surprises are measured over the one-hour period starting 10 minutes before the announcement release in Panel A and over the day of the announcement in Panel B. Coefficients are reported with heteroskedasticity-consistent (White) standard errors in parentheses. One, two, and three asterisks denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 4 – Effects of Fed Funds Rate Surprises on Yields around FOMC Announcements

Security	Interval of Analysis						
	(-35, -5)	(-5, 25)	(25, 55)	(55, 1:25)	(1:25, 1:55)	(1:55, 2:25)	(2:25, 2:55)
3-month bill	-0.013 (0.009)	0.564*** (0.054)	0.086*** (0.017)	0.014 (0.025)	0.041* (0.021)	0.015* (0.008)	0.027*** (0.009)
6-month bill	-0.005 (0.011)	0.472*** (0.070)	0.119*** (0.025)	0.030** (0.013)	0.041*** (0.015)	0.012 (0.009)	0.026*** (0.009)
2-year note	0.016 (0.014)	0.414*** (0.103)	0.057 (0.041)	0.002 (0.024)	0.039** (0.018)	-0.031* (0.017)	0.019* (0.011)
5-year note	0.037*** (0.014)	0.238** (0.107)	0.034 (0.058)	-0.018 (0.024)	0.017 (0.012)	-0.024* (0.011)	0.023 (0.016)
10-year note	0.030** (0.013)	0.060 (0.084)	0.032 (0.073)	-0.013 (0.029)	0.020 (0.018)	-0.005 (0.009)	0.014 (0.023)

Notes: The table reports results from regressions of yield changes on fed funds target rate surprises (both measured in percent) for various 30-minute intervals around the announcement release. Coefficients are reported with heteroskedasticity-consistent (White) standard errors in parentheses. One, two, and three asterisks denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 5 – Correlations of Yield Changes around FOMC Announcements

Security	Interval of Comparison					
	(-35, -5)	(25, 55)	(55, 1:25)	(1:25, 1:55)	(1:55, 2:25)	(2:25, 2:55)
3-month bill	-0.15	0.38***###	0.21**###	0.29***	0.08##	0.44***
6-month bill	-0.21**	0.43***###	0.30***###	0.35***	0.13##	0.39***#
2-year note	0.08	0.39***###	0.15	0.06	0.04	0.27**
5-year note	0.12	0.46***##	0.06	0.01	0.06	0.51***###
10-year note	-0.13	0.41***##	0.18#	-0.04	-0.20	0.38***###

Notes: The table reports Pearson correlation coefficients of yield changes in the 30-minute interval starting five minutes before the announcement release and various other 30-minute intervals around the announcement. One, two, and three asterisks (number signs) denote significance of the Pearson (Spearman) correlation coefficient at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 6 – Profitability of Momentum-Based Trading Strategy around FOMC Announcements

Security	Trade at Midpoint		Buy (Sell) at Offer (Bid)	
	Yield Pick-Up (in Basis Points)	Profit in Dollars (per \$1 Million Par)	Yield Pick-Up (in Basis Points)	Profit in Dollars (per \$1 Million Par)
3-month bill	0.60***	18***	-0.29	-7
6-month bill	0.64***	30***	-0.40*	-20*
2-year note	1.45***	270***	0.56*	103*
5-year note	1.11***	474***	0.46	198
10-year note	0.92***	693***	0.42	313

Notes: The table reports the average expected profits from following a strategy of buying (selling) a security 25 minutes after an announcement if the price has increased (decreased) over the preceding 30 minutes, and selling (buying) the security one hour later. Columns 2 and 3 report profits assuming one could trade at the bid-ask midpoint whereas columns 3 and 4 report profits assuming one buys (sells) at the offer (bid). Profits are reported in terms of yield pick-up and dollars per \$1 million par trade size, excluding brokerage fees. One, two, and three asterisks denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 7 – Effects of FOMC Announcements on Yield Volatility

Security	Interval of Analysis						
	(-35, -5)	(-5, 25)	(25, 55)	(55, 1:25)	(1:25, 1:55)	(1:55, 2:25)	(2:25, 2:55)
3-month bill	0.52	3.46***	0.98***	0.72***	0.49**	0.34	0.27
	0.43	0.45	0.38	0.31	0.30	0.30	0.26
6-month bill	0.63*	3.42***	1.17***	0.63***	0.55***	0.41**	0.29
	0.44	0.45	0.41	0.32	0.29	0.29	0.25
2-year note	0.74	4.50***	2.00***	1.04***	0.78***	0.72***	0.45
	0.76	0.79	0.78	0.57	0.50	0.45	0.42
5-year note	0.83	3.75***	2.15***	1.02***	0.62*	0.58*	0.50
	0.82	0.85	0.85	0.58	0.51	0.45	0.41
10-year note	0.71	2.96***	2.13***	0.97***	0.54	0.44	0.57***
	0.79	0.84	0.82	0.55	0.47	0.42	0.37

Notes: The table reports average absolute yield changes (in basis points) in various 30-minute intervals around the announcement release and average absolute yield changes on nonannouncement days for the same interval. One, two, and three asterisks denote significance of the differences at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 8 – Effects of FOMC Announcements on Trading Volume

Security	Interval of Analysis						
	(-35, -5)	(-5, 25)	(25, 55)	(55, 1:25)	(1:25, 1:55)	(1:55, 2:25)	(2:25, 2:55)
3-month bill	89.9	264.1***	208.1***	109.0***	73.6**	53.9**	41.8
	69.9	65.4	60.7	43.2	36.5	30.3	20.1
6-month bill	58.0	145.0***	180.4***	73.2***	43.8***	42.9**	16.7
	58.6	52.2	48.5	28.7	26.8	22.5	15.3
2-year note	247.9	614.9***	556.8***	285.7***	196.8***	163.2***	111.2
	258.9	262.7	256.8	160.8	137.5	110.0	93.2
5-year note	210.2	426.5***	390.4***	207.8***	156.3	130.1*	116.0**
	234.3	247.7	239.6	148.9	128.0	104.2	85.6
10-year note	144.0	241.7***	249.4***	153.3***	115.1**	95.7**	82.3**
	155.4	164.6	166.1	106.6	90.0	76.4	61.2

Notes: The table reports average trading volume (in millions of dollars) for various 30-minute intervals around the announcement release and average trading volume on nonannouncement days for the same interval. One, two, and three asterisks denote significance of the differences at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 9 – Effects of FOMC Announcements on Bid-Ask Spreads

Security	Interval of Analysis						
	(-35, -5)	(-5, 25)	(25, 55)	(55, 1:25)	(1:25, 1:55)	(1:55, 2:25)	(2:25, 2:55)
3-month bill	0.71	1.37***	0.94***	0.83**	0.78*	0.76	0.84
	0.67	0.65	0.66	0.65	0.68	0.74	0.87
6-month bill	0.84	1.56***	0.96***	0.94***	0.88*	0.86	1.02
	0.74	0.73	0.72	0.73	0.75	0.79	0.89
2-year note	0.71	1.36***	1.05***	0.91***	0.82**	0.80**	0.81*
	0.66	0.64	0.65	0.65	0.64	0.64	0.67
5-year note	0.63	0.98***	0.78***	0.67**	0.56	0.50	0.47
	0.54	0.55	0.55	0.53	0.50	0.48	0.48
10-year note	0.50	0.72***	0.55	0.52	0.45	0.41	0.50
	0.48	0.49	0.48	0.46	0.45	0.42	0.43

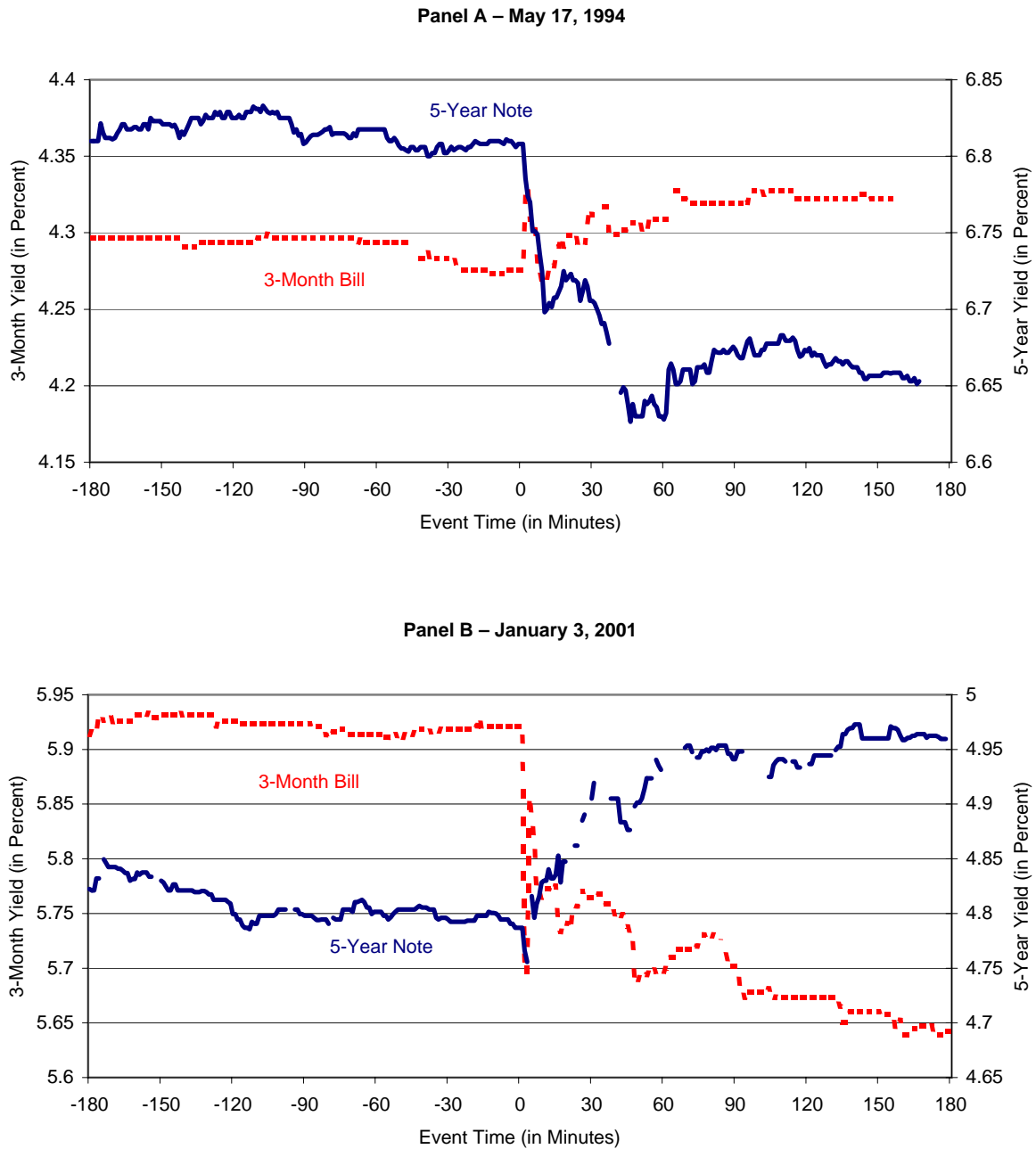
Notes: The table reports average bid-ask spreads (in basis points) for various 30-minute intervals around the announcement release and average bid-ask spreads on nonannouncement days for the same interval. One, two, and three asterisks denote significance of the differences at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 10 – Effects of FOMC Announcement Time Variation on Market Functioning

Security	Effects of Expected Announcement Occurring One Minute Later					
	Bid-Ask Spread in preceding 10 Minutes		Likelihood of Quote in preceding 10 Minutes		Length of Time without Posted Quote	
3-month bill	0.048	(0.055)	-0.102**	(0.046)	1.526***	(0.489)
6-month bill	0.188**	(0.088)	-0.060	(0.057)	0.543	(0.487)
2-year note	0.008	(0.049)	-0.123**	(0.049)	1.134**	(0.495)
5-year note	0.097	(0.072)	0.000	(0.048)	-0.216	(0.587)
10-year note	0.104	(0.108)	-0.008	(0.031)	0.267	(0.397)

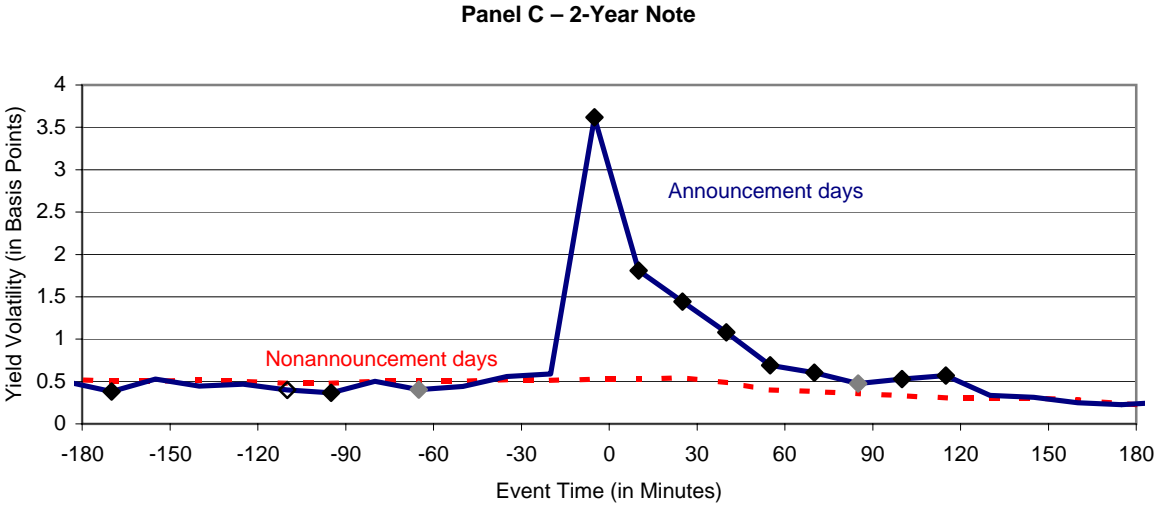
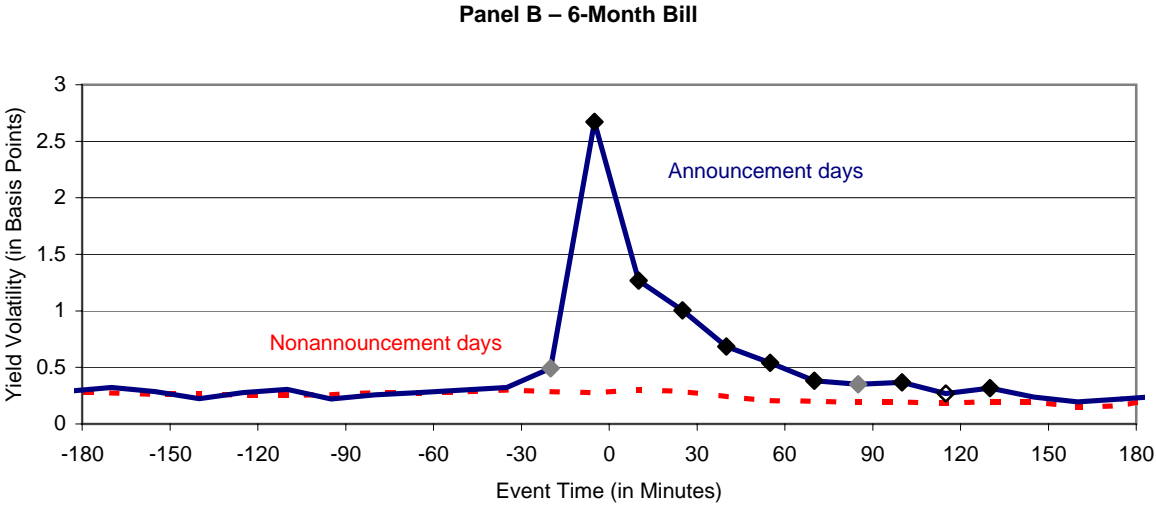
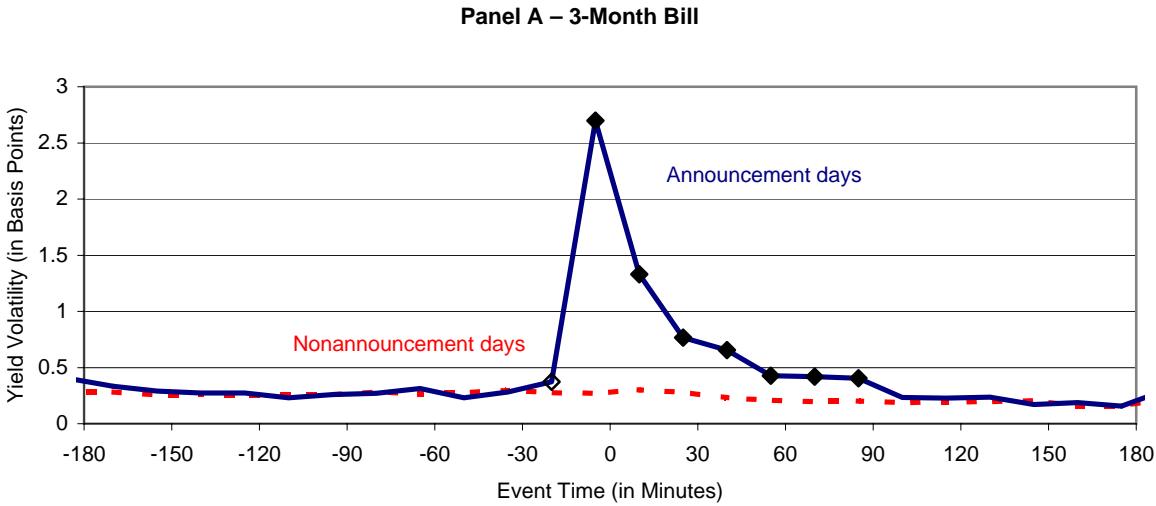
Notes: The table reports how variation in FOMC announcement time affects market functioning for 83 announcements expected around 2:15 p.m. (the analyses exclude five inter-meeting announcements, four other announcements that did not occur right around 2:15, and the first announcement that did occur around 2:15). The second column reports slope coefficients from least squares regressions of average bid-ask spreads in the 10 minutes preceding an announcement (in basis points) on announcement time (in minutes). The fourth column reports slope coefficients from two-sided censored (Tobit) regressions of the likelihood of a quote being posted in the 10 minutes preceding an announcement on announcement time (the dependent variable is censored between zero and one). The sixth column reports slope coefficients from one-sided censored (Tobit) regressions of the length of time around an announcement without a posted quote (in minutes) on announcement time (the dependent variable is left-censored at one). All models include control variables for the average spread (column 2) or quote likelihood (columns 4 and 6) in the three-hour period ending 15 minutes before announcement. Robust standard errors are reported in parentheses. One, two, and three asterisks denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Figure 1 – Select Responses to FOMC Announcements

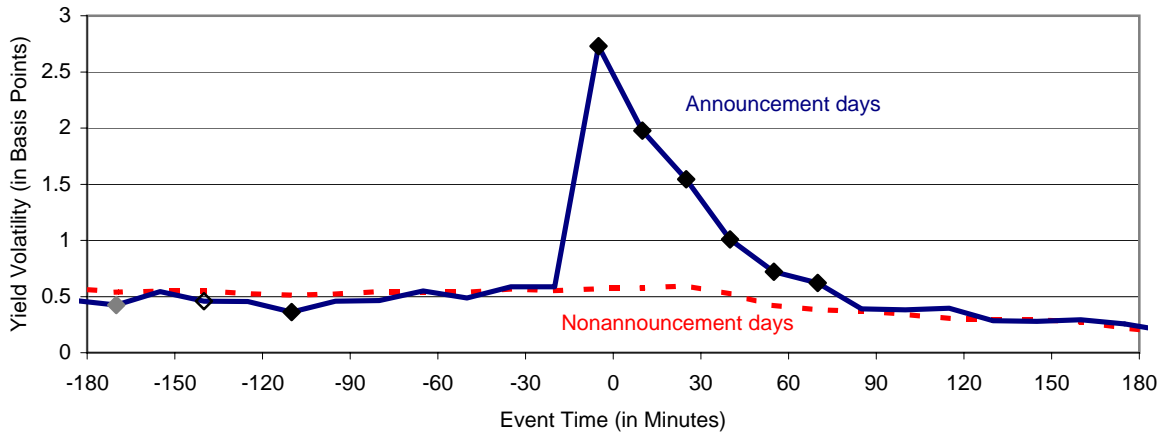


Note: The figure plots 3-month bill and 5-year note yields on a minute-by-minute basis around the release of the May 17, 1994 and January 3, 2001 FOMC announcements.

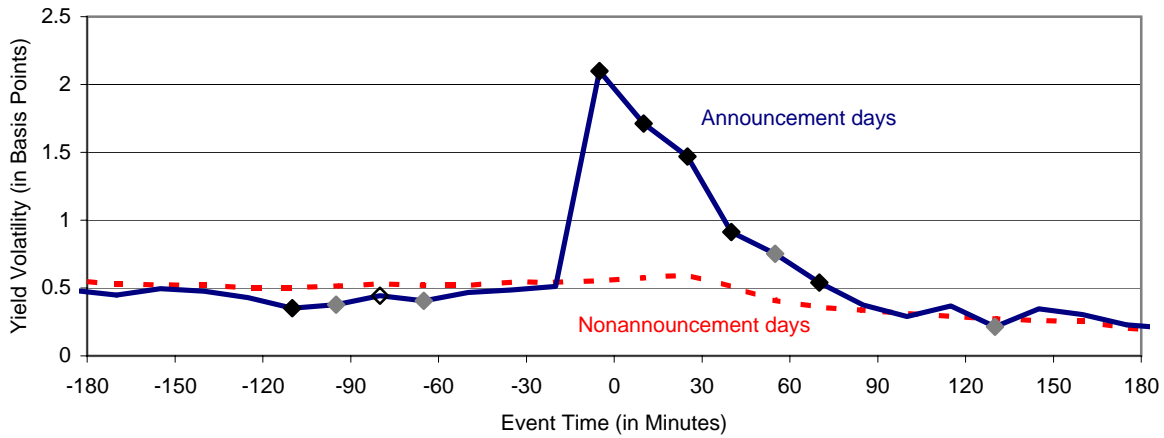
Figure 2 – Yield Volatility on FOMC Announcement and Nonannouncement Days



Panel D – 5-Year Note

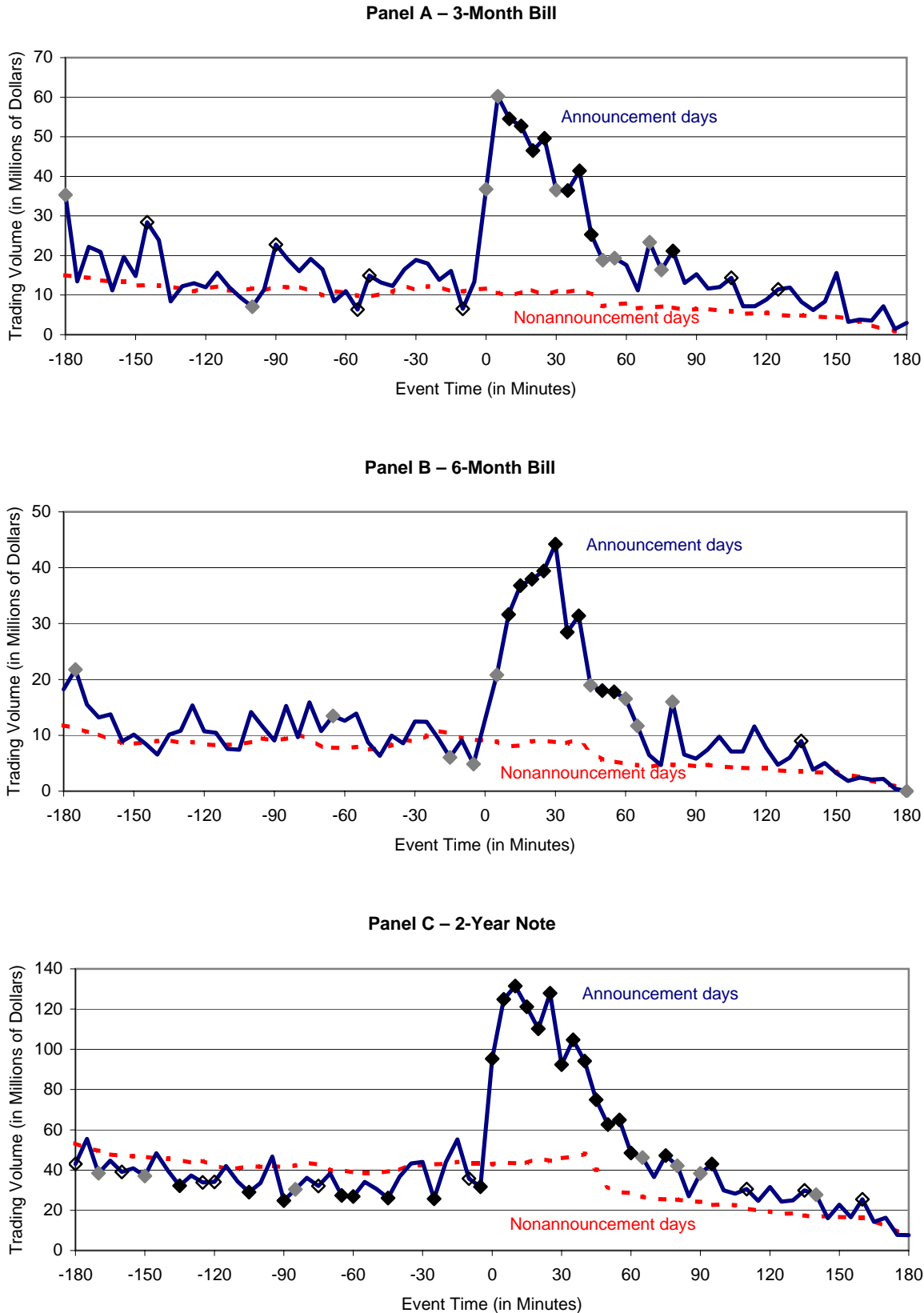


Panel E – 10-Year Note

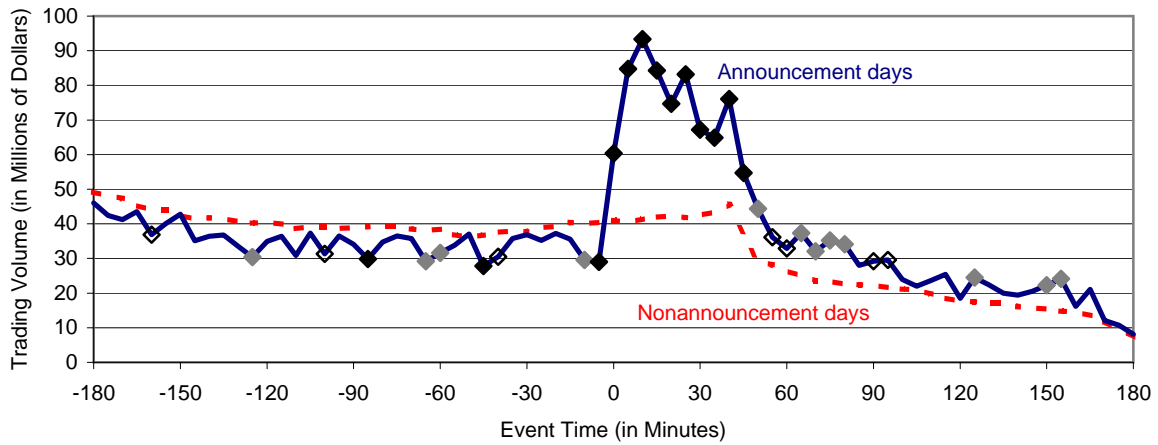


Notes: The figure plots average absolute yield changes in 15-minute intervals around the announcement release and average absolute yield changes on nonannouncement days for the same interval. Times shown are interval start times. The interval including the announcement release runs from 5 minutes before to 10 minutes after announcement. White, gray, and black diamonds denote significance of the differences at the 10 percent, 5 percent, and 1 percent levels, respectively.

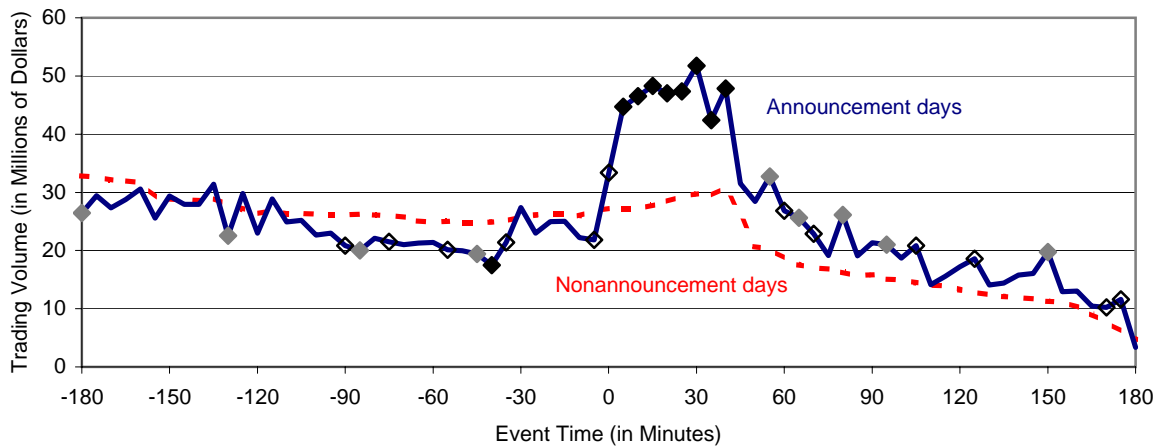
Figure 3 – Trading Volume on FOMC Announcement and Nonannouncement Days



Panel D – 5-Year Note

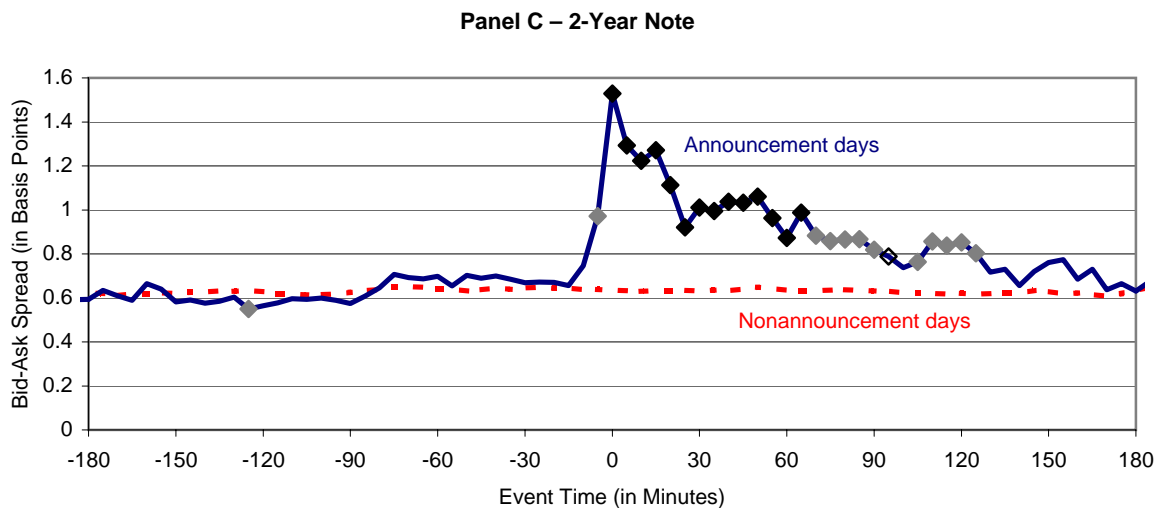
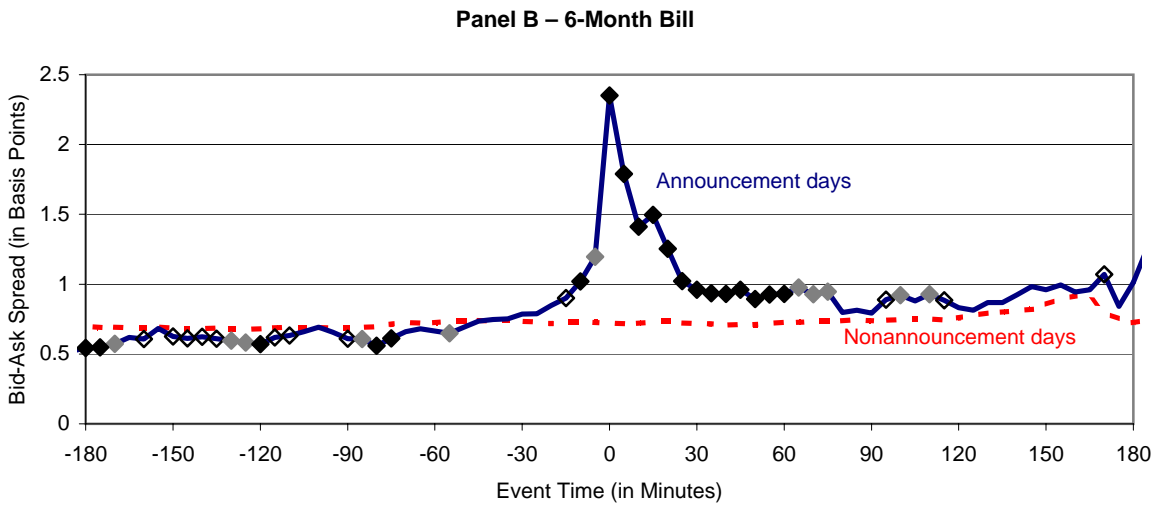
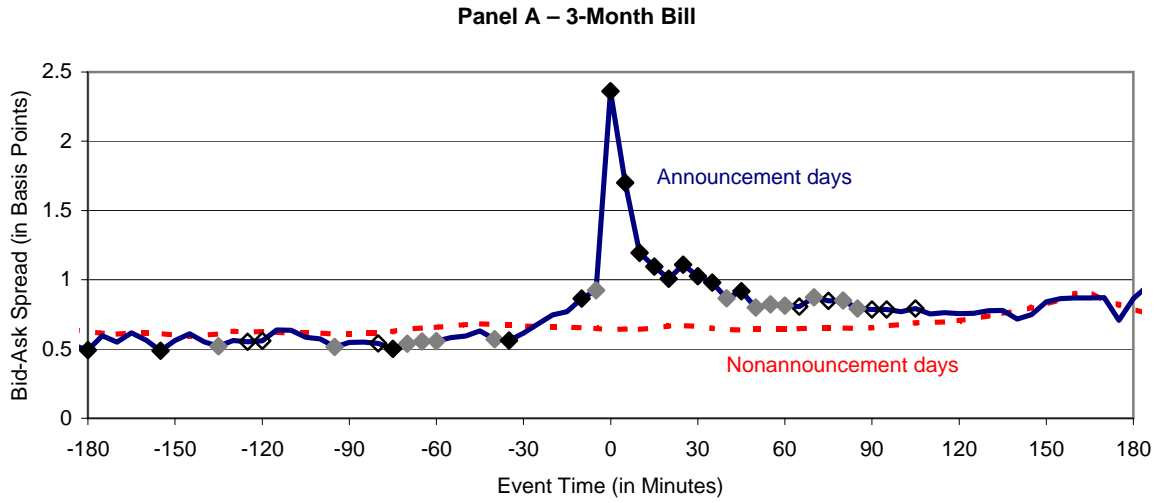


Panel E – 10-Year Note

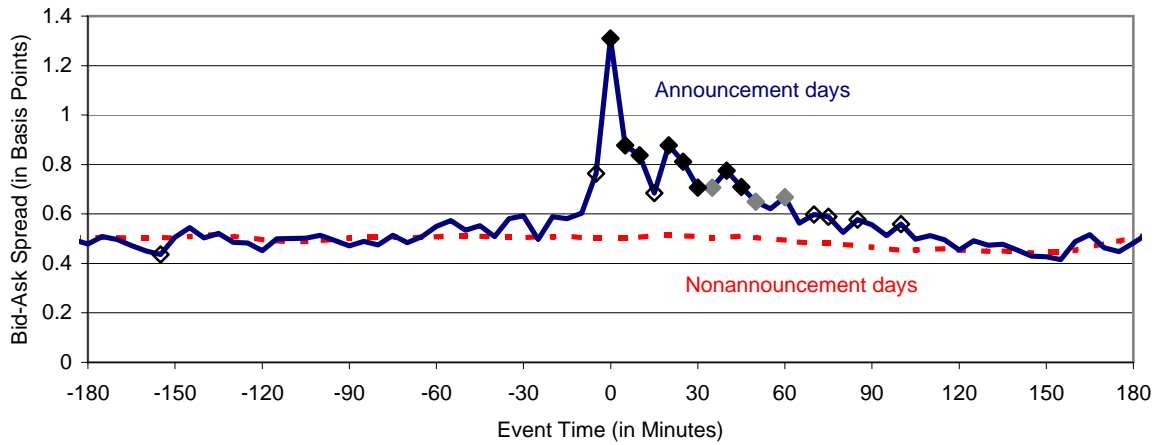


Notes: The figure plots average trading volume in five-minute intervals around the announcement release and average trading volume on nonannouncement days for the same interval. Times shown are interval start times. White, gray, and black diamonds denote significance of the differences at the 10 percent, 5 percent, and 1 percent levels, respectively.

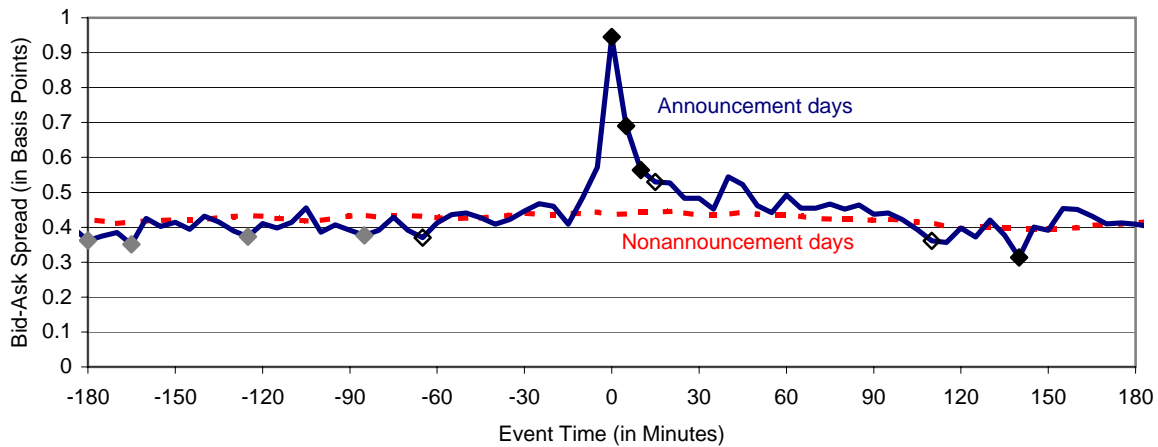
Figure 4 – Bid-Ask Spreads on FOMC Announcement and Nonannouncement Days



Panel D – 5-Year Note

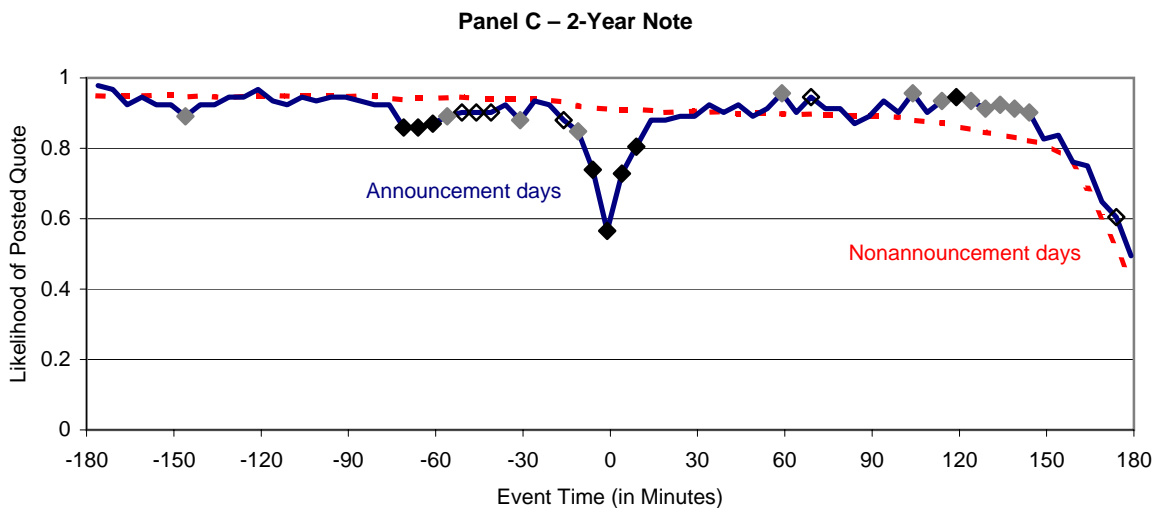
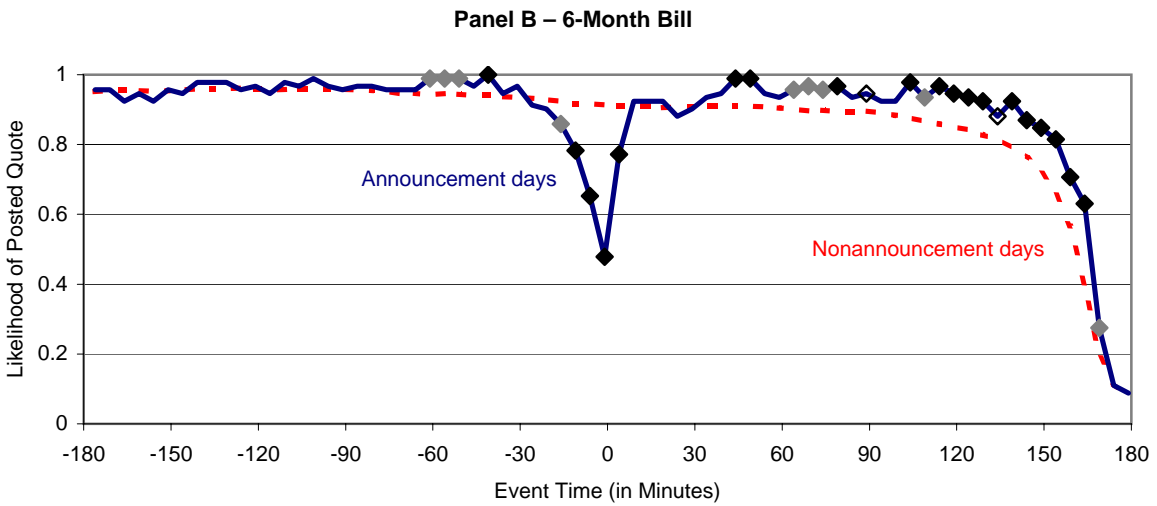
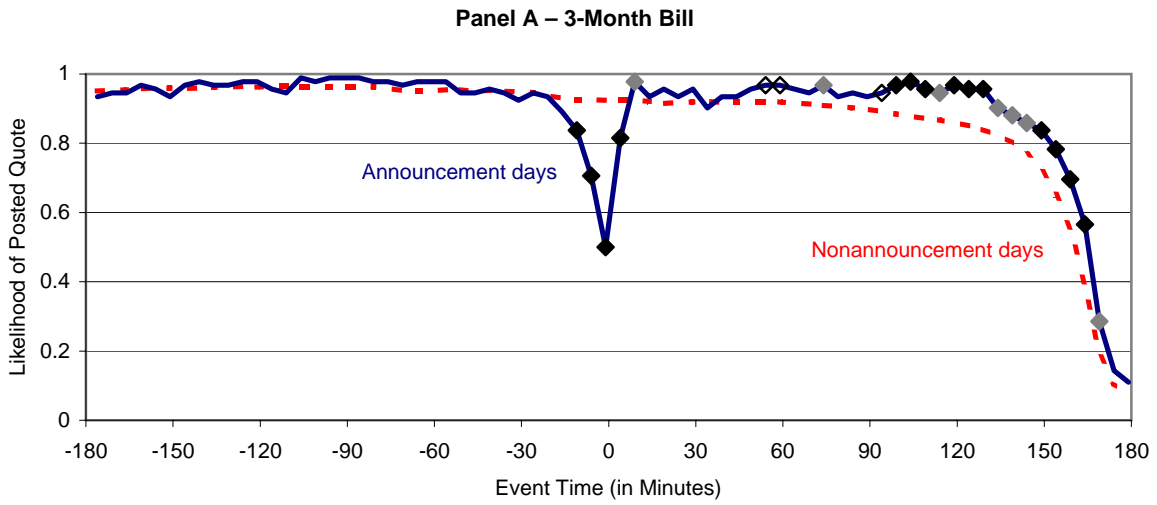


Panel E – 10-Year Note

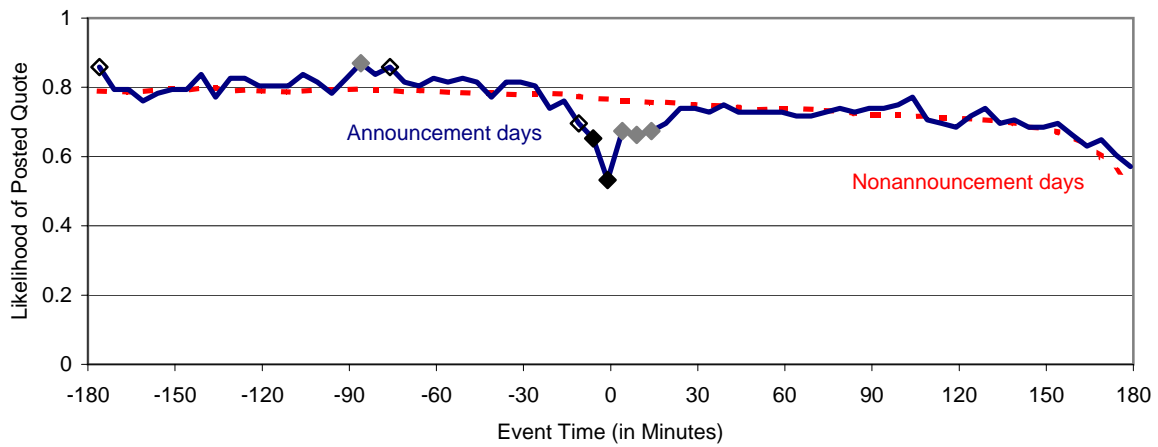


Notes: The figure plots average bid-ask spreads in five-minute intervals around the announcement release and average bid-ask spreads on nonannouncement days for the same interval. Times shown are interval start times. White, gray, and black diamonds denote significance of the differences at the 10 percent, 5 percent, and 1 percent levels, respectively.

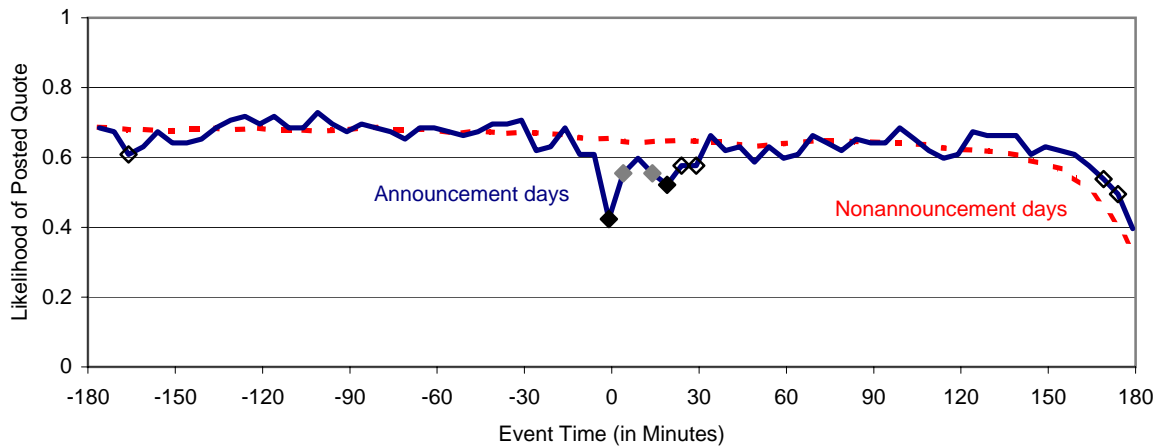
Figure 5 – Likelihood of Posted Quote on FOMC Announcement and Nonannouncement Days



Panel D – 5-Year Note



Panel E – 10-Year Note



Notes: The figure plots the likelihood of there being a posted interdealer quote for a security at the end of five-minute intervals around the announcement release and at the ends of the same intervals on nonannouncement days. Times shown are interval end times. White, gray, and black diamonds denote significance of the differences at the 10 percent, 5 percent, and 1 percent levels, respectively.