PRELIMINARY – COMMENTS WELCOME

The Microstructure of the TIPS Market*

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Abstract

We characterize the microstructure of the market for Treasury inflation-protected securities (TIPS) using novel tick data from the interdealer market. We find a marked difference in trading activity between on-the-run and off-the-run securities, as in the nominal Treasury market. We find little difference in quoted bid-ask spreads or quoted depth between on-the-run and off-the-run securities, in contrast to the nominal market, but we do find a sharp difference in the prevalence of quotes. Intraday activity differs strikingly from the nominal market, with activity peaking in the late morning. Announcement effects also differ from the nominal market, with auction results and consumer price index announcements eliciting particularly sharp increases in trading activity.

Keywords: Treasury inflation-protected securities, liquidity, seasonality, announcements

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1. Introduction

The introduction of inflation-indexed securities in the U.S. in 1997 offered multiple potential benefits. First and foremost, the development was intended to offer investors a security enabling them to hedge inflation. By taking on the risk of inflation, the Treasury would not have to pay an inflation risk premium on its securities, thereby lowering its borrowing costs.[1] An ancillary benefit of the securities is that they would provide a market-based measure of inflation expectations. In particular, one could gauge market expectations of inflation by comparing the yields on nominal Treasury securities to yields on inflation-indexed securities of comparable maturities.

The potential benefits of inflation-indexed securities have not been fully realized because of the securities' lack of liquidity as compared to nominal securities. The reduced liquidity of inflation-indexed securities is thought to result in the securities having a liquidity premium relative to nominal securities, offsetting the inflation risk premium.[2] Similarly, the existence of a liquidity premium in inflation-indexed securities complicates inferences of inflation expectations, particularly if the premium changes over time. Despite the importance of the liquidity of inflation-indexed securities, and the market's large size ($516 billion as of July 31, 2008), there is virtually no quantitative evidence on the securities' liquidity.

The Federal Reserve collects and publishes data on trading volume in TIPS, which show that trading activity in TIPS is much lower than that in nominal securities. However,

[1] Campbell and Shiller (1997) estimate the inflation risk premium for a 5-year nominal bond to be between 50 and 100 basis points. Buraschi and Jiltsov (2005) estimate the 10-year inflation risk premium to average 70 basis points.

[2] D'Amico, Kim, and Wei (2008), for example, estimate that TIPS yields contain a liquidity premium that was until recently quite large (about 1%). Sack and Elsasser (2004) argue that TIPS have not reduced Treasury's financing costs because of several factors, including the lower liquidity of TIPS, whereas Roush (2008) argues that TIPS have saved the government money – absent the early years of the program – because of investors' willingness to pay to insure against inflation risk. Gurkaynak, Sack, and Wright (2008) also find that inflation compensation was held down in the early years by the illiquidity of TIPS.

the Fed data are aggregated over the week and across all TIPS and only provide information on trading volume. Such data are unable to provide information about activity in particular TIPS, activity over the day or week, or other measures of TIPS liquidity, such as bid-ask spreads.

In this paper, we use novel tick data from the interdealer market to characterize the liquidity of the market for TIPS. We examine how trading activity breaks down across different sectors, over securities' life cycles, and over the trading day. We also characterize liquidity using a variety of different measures, including bid-ask spreads, quoted depth, and the prevalence with which there is a two-sided market in TIPS. Lastly, we analyze how major announcements affect TIPS activity and how the market adjusts to such announcements.

Our paper is most related to the literature examining the microstructure of the nominal Treasury securities market and particularly studies that characterize the liquidity of the market (Fleming (1997)), liquidity over securities' life cycles (Fleming (2002), Goldreich, Hanke, and Nath (2005), and Barclay Hendershott and Kotz (2006)) and the announcement adjustment process (Fleming and Remolona (1999), Balduzzi, Elton, and Green (2001), and Fleming and Piazzesi (2005)). The paper is also related to studies of announcement effects in the indexed markets, and especially Beechey and Wright (2008), who also analyze intraday data, but is distinguished from those studies in its focus on liquidity and the announcement adjustment process as opposed to price level effects.

We find a marked difference in trading activity between on-the-run and off-the-run securities, as in the nominal market.[3] We find little difference in quoted bid-ask spreads or

[3] On-the-run securities are the most recently issued securities of a given maturity. Off-the-run securities are previously issued securities of a given maturity.

quoted depth between on-the-run and off-the-run securities, in contrast to the nominal market, but we do find a sharp difference in the prevalence of quotes. The findings suggest that trading activity and "market prevalence" are good cross-sectional measures of TIPS liquidity, but that bid-ask spreads and quoted depth are not.

We also find several differences in intraday patterns and announcement effects between TIPS and nominal securities, likely reflecting the different uses, ownership, and cash flow attributes of the securities. In particular, we find that intraday TIPS activity peaks later in the morning than intraday nominal activity. We also find that TIPS auctions and consumer price index announcements spur significant increases in trading activity, whereas employment reports do not. A high-frequency analysis highlights announcement effects which differ from those found in the nominal market.

The paper proceeds as follows. In Section 2, we discuss institutional features of the market for TIPS. In Section 3, we describe the tick data used in our empirical analysis. In Section 4, we report our empirical results, including trading activity by sector, the liquidity of on-the-run and off-the-run securities, intraday patterns in trading activity and liquidity, and the effects of major announcements. Section 5 concludes.

2. Market Structure

Treasury inflation-protected securities were introduced by the U.S. Treasury Department in January 1997. The principal of these securities is adjusted for inflation over time according to the consumer price index for urban consumers. Semi-annual interest payments are a fixed percentage of the inflation-adjusted principal and the greater of the inflation-adjusted principal and the original principal is paid at maturity.

The Treasury currently issues TIPS with original maturities of 5, 10, and 20 years. New 5-year notes are issued once a year in April and then reopened in October (a reopening refers to the additional issuance of an outstanding security). New 10-year notes are issued in January and July, and reopened in April and October, respectively. New 20-year bonds are issued in January and reopened in July. 30-year bonds are not currently issued, but were issued between 1998 and 2001.

TIPS are sold in the primary market via single price auctions, like nominal Treasury securities, and are disproportionately purchased at auction by domestic investment accounts. Analyzing Treasury Department data, Fleming (2007) finds that investment funds (which include mutual funds and hedge funds) account for 30.2% of TIPS sold at auction, but only 11.5% of nominal notes and bonds. In contrast, dealers and brokers account for 56.3% of TIPS sold at auction versus 63.6% of nominal notes and bonds and foreign and international investors account for 8.2% of TIPS sold at auction versus 21.1% of nominal notes and bonds.

The secondary market structure for TIPS is also similar to that for nominal Treasury securities. Trading takes place in a multiple-dealer over-the-counter market. The predominant marketmakers are the so-called primary dealers – those dealers with a trading relationship with the Federal Reserve. The dealers trade with the Fed, their customers, and one another. Nearly all interdealer trading occurs via interdealer brokers.

Interdealer brokers provide dealers and other financial firms with electronic screens posting the best bid and offer prices provided by dealers (either electronically or by phone) along with the associated quantities. Quotes are binding until and unless withdrawn. Dealers execute trades by contacting the brokers (either electronically or by phone), who post the resulting trade price and size on their screens. The brokers thus match buyers and sellers,

while ensuring anonymity, even after a trade. In compensation for their services, the brokers charge a fee.

An interesting feature of interdealer trading is the brokers' expandable limit order protocol. As explained in Boni and Leach (2004), a Treasury market trader whose order has been executed has the right-of-refusal to trade additional volume at the same price. In addition to such "workups," electronic systems allow traders to enter "iceberg" orders, whereby a trader can choose to show only part of the amount he is willing to trade. There is an incentive to display quantity, however, or at least enter it as hidden, because shown quantity takes priority over hidden quantity, and hidden quantity at a given price is executed against before a workup starts. Fleming and Mizrach (2008) find that hidden depth accounts for only a small share of total depth in the nominal market.

Much of the activity in TIPS occurs on an outright cash-for-security basis, as is typical in the nominal market. However, a large share of TIPS activity occurs via breakeven-inflation trades, whereby a particular inflation-protected security is traded against a proportionate quantity of a particular nominal security. Some TIPS are also traded via issue-for-issue switch trades, whereby a particular inflation-protected security is traded against a proportionate quantity of another inflation-protected security. In contrast to the nominal market, there is no organized futures market in TIPS.[4]

Data on outstanding ownership of TIPS is less comprehensive and more dispersed than the information on the buyers of securities at auction. Positions data reported to the Federal Reserve Bank of New York by the primary dealers show that the dealers' aggregate holdings of TIPS averaged $2.2 billion over the March 2, 2005 to March 26, 2008 period (a

[4] Futures for 5- and 10-year TIPS were listed on the Chicago Board of Trade between July 1997 and March 1998, and futures on the 20-year bond were listed between April 1998 and June 2000.

period closely corresponding to the paper's sample period), and ranged from -$3.2 billion to $8.1 billion. In contrast, nominal Treasury note and bond holdings averaged -$125.6 billion over this period, and ranged from -$178.6 billion to -$65.1 billion.[5] Mutual funds also provide detailed reports of their holdings, including their holdings of TIPS, but such information is widely dispersed.[6]

3. Data

Our analysis is based on proprietary tick data for outright trading of TIPS in the interdealer market. Our sample period runs from March 4, 2005 to March 27, 2008. We retain 757 trading days in our analysis after excluding 32 holidays and 11 trading days on which data are missing for much of the day.[7] We retain trading days when data are available for all securities except the on-the-run 10-year note (244 days) and/or 20-year bond (224 days). In such cases, we impute trading activity for these securities based on the security's share of overall TIPS volume for days when data are not missing.

Twenty-seven TIPS are outstanding over all or part of our sample period, comprising three 5-year notes, 17 10-year notes, four 20-year bonds, and three 30-year bonds. Eleven (11) of the 27 TIPS were first issued during the sample period, comprising two 5-year notes, six 10-year notes, and three 20-year bonds. Two TIPS matured during the sample period, both 10-year notes.

[5] Fleming and Rosenberg (2008) analyze how dealers manage their nominal Treasury positions.
[6] The largest TIPS fund (Vanguard Inflation-Protected Securities Fund), for example, reported $16.6 billion in TIPS holdings as of December 31, 2008, accounting for 3.1% of the $530 billion in TIPS outstanding on that date.
[7] In particular, we exclude days in which we are missing at least two consecutive hours of activity during New York trading hours for all TIPS.

Outright TIPS trading over our sample averages $562 million per day. In contrast, total interdealer trading in TIPS over this same period as reported by the primary dealers (and including significant double-counting) averaged $2,611 million per day. A comparison of these numbers suggests that the outright trading in our dataset accounts for about 42% of interdealer TIPS trading.[8] Breakeven inflation trading and issue-for-issue switch trading probably account for much of the difference.

To put the TIPS trading numbers in context, primary dealers report nominal interdealer trading over the same period of $232 billion per day, on average. That is, TIPS account for just over 1% of Treasury trading in the interdealer market over our sample period. In contrast, TIPS account for about 7% of marketable Treasury debt at the beginning of our sample period and 10% at the end of our sample period.[9] The turnover ratio for TIPS is thus only about 1/7 to 1/10 the turnover ratio for nominal Treasury securities.

As noted, one feature of interdealer trading is the presence of work-ups and hidden orders. Our data is processed in a manner that aggregates the outcome of each workup into a single trade (most microstructure studies of the nominal Treasury market process their data in the same manner). That is, any particular trade in our dataset was conducted at a particular price, and at virtually the same time, but may have occurred in a sequence of steps, possibly with multiple counterparties. Based on this trade definition, we find an average daily number of trades of 69 over our sample and an average trade size of $7.1 million.

[8] It is somewhat problematic to directly compare these numbers, because our outright volume may include some trading by non-primary dealers and because the interdealer numbers reported to the Fed (on the FR 2004 report) include significant double-counting. That said, discussions with market participants suggest that virtually all interdealer broker trading of TIPS is in fact between primary dealers. Assuming only primary dealers trade on interdealer platforms, then our data coverage share equals our outright volume divided by one-half of FR 2004 interdealer broker volume.

[9] The percentages are calculated using the Treasury's Monthly Statement of the Public Debt from February 2005 and March 2008, posted at << http://www.treasurydirect.gov/govt/reports/pd/mspd/mspd.htm>>.

4. Results

A. Trading Activity by Sector

Trading activity in TIPS is concentrated in notes, and more so than would be implied by issuance amounts alone. In terms of daily trading volume by sector, $403 million, or 71.6% of all TIPS activity, occurs in 10-year notes, $110 million (19.5%) in 5-year notes, and $50 million (8.9%) in 20- and 30-year bonds (Table 1). Bonds account for 25.9% of TIPS outstanding at the beginning of our sample period and 27.2% at the end of our sample period. It follows that the turnover ratio for bonds is less than one-third of that for notes.[10] A similar pattern is observed in the nominal market, with the pattern likely reflecting greater hedging and speculative trading demands for notes.[11]

An alternative breakdown of volume, by time to maturity, shows that most activity occurs in TIPS maturing within five years (Table 2). Interestingly, only half of the volume in TIPS originally issued as 10-year notes occurs when the securities have more than 5 years to maturity (198.0/402.7 = 0.49). This suggests that some 10-year notes continue to be actively traded years after issuance.

The pattern for number of trades is similar to that for volume, but less skewed toward notes, reflecting a higher average trade size for notes. Average trade size ranges from $9.5 million for 5-year notes to $3.2 million for 30-year bonds. This pattern is also observed in the nominal market (e.g., Fleming (2003) and Fleming and Mizrach (2008)), and probably reflects the higher duration and hence price volatility of the longer maturity instruments.

[10] Assuming a 26.5% issuance share, 8.9%/26.5% equals 0.335, whereas (1-8.9%)/(1-26.5%) equals 1.239, which is 3.7 times larger than 0.335.

[11] Over the March 2, 2005 to March 26, 2008 period, for example, dealers reported average daily trading volume of $125.4 billion in nominal notes and bonds with times to maturities of more than 6, but not more than 11 years, and $29.5 billion in nominal notes and bonds with times to maturities of more than 11 years.

B. Liquidity of On-the-Run and Off-the-Run Securities

Trading activity for on-the-run TIPS is substantially higher than it is for off-the-run TIPS (Table 3). Daily trading in the on-the-run 10-year note thus averages $136 million, more than six times higher than average trading volume ($22 million) of individual off-the-run 10-year notes. The comparable ratio for the 5-year note is just over three ($87 million versus $27 million) and it is somewhat less than five for the 20-year bond ($30 million versus $6 million). Such on-the-run/off-the-run differentials are just as striking in the nominal market (Fleming (2002), Fabozzi and Fleming (2005), Goldreich, Hanke, and Nath (2005), and Barclay, Hendershott, and Kotz (2006)), reflecting a concentration of liquidity in just a few securities, and in those securities that tend to have the largest floating supplies.

While there is a similar on-the-run/off-the-run divergence in daily trading frequency, such a pattern is not evident in trade size. In fact, average trade sizes are actually slightly higher for off-the-run TIPS. For the 10-year note, for example, average on-the-run trade size is $7.2 million whereas average off-the-run trade size is $9.0 million. Barclay, Hendershott, and Kotz (2006) uncover a similar pattern in the nominal market, whereas Goldreich, Hanke, and Nath (2005) report smaller trade sizes for off-the-run securities. One explanation for our finding is that there is a composition change in the type of trades executed when a security goes off-the-run, with a proportional reduction in frequent, small, speculative trades resulting in a higher trade size despite lower overall activity.[12]

The change in trading volume that occurs when a security goes off the run is quite abrupt in the TIPS market (Chart 1A). Trading volume thus averages $95 million per day in the last 60 days before a security goes off-the-run and $14 million in the first 60 days it is

[12] Barclay, Hendershott, and Kotz (2006) find that interdealer trading in the Treasury market migrates from electronic brokers to voice brokers when securities go off-the-run, which could be related to such a compositional change in the type of trading.

off-the-run. Moreover, average daily volume plunges from $233 million on the last day a security is on-the-run (that is, the auction day of the next security) to $45 million the day after. The pattern is even more striking when examined in terms of trading frequency (Chart 1B). Similar patterns for nominal Treasury securities are reported by Fleming (2002), Goldreich, Hanke, and Nath (2005), and Barclay, Hendershott, and Kotz (2006).

Despite the sharp volume differential between on-the-run and off-the-run TIPS, there is virtually no difference in average quoted bid-ask spreads or quoted depth between on-the-run and off-the-run securities (Table 4). Quoted bid-ask spreads average two to three 32nds for on-the-run and off-the-run 5- and 10-year notes (a point equals one percent of par), and close to seven 32nds for 20-year bonds. The average quantity available at the inside bid and offer prices is only somewhat higher than the minimum quote size of $1 million for on-the-run and off-the-run TIPS in all sectors. Such findings differ markedly from the nominal market, where studies find a sharp widening of bid-ask spreads and decrease in quoted depths when securities go off-the-run (Fleming (2002) and Goldreich, Hanke, and Nath (2005)).

A notable aspect of average quote sizes is that they are dwarfed by average trade sizes. For example, the average quote size for the on-the-run 10-year note is $1.3 million but the average trade size for the note is $7.2 million. The most important reason for the discrepancy is probably the "work-up" process, whereby the initial buyer and seller, as well as additional buyers and sellers, can agree to trade additional amounts at the same price. Trade sizes reflect the total amounts traded in a single work up. Studies of the nominal market have found average trade sizes to exceed average quote sizes to a lesser degree, and only for bills and off-the-run notes (Fleming (2002, 2003) and Goldreich, Hanke, and Nath (2005)).

An additional reason for the discrepancy between quote sizes and trade sizes is that the quoted sizes only reflect *shown* amounts. Dealers can enter iceberg orders, however, whereby they commit to buying or selling a certain quantity at a certain price, with part of the quantity visible on the broker screen and the remainder hidden. Hidden amounts become visible to the market incrementally if and only if the initial shown amount is traded against. As mentioned earlier, hidden depth accounts for only a small share of total depth in the nominal market.

While bid-ask spreads and quoted depth are similar for on-the-run and off-the-run securities, "market prevalence" is markedly higher for on-the-run securities. Market prevalence gauges the percent of time there is a two-sided market in a security (that is, both a firm bid and offer quote). This proportion averages close to 60% for the on-the-run 10-year note (during New York trading hours, defined as 7:30 a.m. to 5:30 p.m.), but only about 15% for any given off-the-run 10-year note. That is, for off-the-run 10-year notes, there is a one-sided quote, or no quote, about 85% of the time.

The results, taken together, highlight the limitations of the bid-ask spread and quoted depth as liquidity measures. Such spreads and depth are similar for on-the-run and off-the-run securities when they are available, but are available much less frequently for off-the-run securities. That is, measured liquidity among TIPS in a particular sector largely varies across the market prevalence dimension as opposed to the spread or quoted depth dimensions. In contrast, liquidity is found to vary across all of these dimensions in the nominal market.

C. Intraday Patterns

Intraday trading volume in TIPS is concentrated in the mid to late morning, roughly 9 a.m. to 11:30 a.m., and again in the afternoon right before 3 p.m. (Chart 2A).[13] Trading frequency shows a similar pattern, whereas average trade size is fairly stable across the day (Charts 2B and 2C). The morning pattern diverges from that for the nominal market, where activity peaks between 8:30 and 9 a.m. (e.g., Fleming (1997) and Fleming and Mizrach (2008)). The morning peak in the nominal market is largely explained by the release of several important macroeconomic announcements at 8:30 a.m. (Fleming and Remolona (1999)).

The later morning peak in activity in the indexed market may reflect differences in uses and ownership between nominal and inflation-protected securities. In particular, TIPS activity is probably driven more by institutional trading demands which are best met when the market is less volatile and trading costs are lower (that is, after the 8:30 a.m. announcements and occasional 9:15 and 10:00 a.m. announcements). In contrast, speculative and hedging considerations may dominate in the nominal market, causing activity to peak shortly after announcement, despite the high volatility and trading costs.

The peak before 3 p.m. also occurs in the nominal market, but is more pronounced for TIPS. This perhaps again reflects differences in uses and ownership between nominal and inflation-protected securities. In particular, TIPS activity is probably driven more by institutional investors, who are more likely to be managing relative to a benchmark and who therefore want to trade as close to 3 p.m. as possible to minimize tracking error (fixed income indices are priced at 3 p.m.). Consistent with this argument, we find that TIPS trading

[13] While the intraday patterns are only presented for the on-the-run 10-year note, results are qualitatively similar for other securities.

volume is particularly high on the last day of the month, when fixed income indices are rebalanced, and that the peak in trading before 3 p.m. is particularly high on that day.

One other difference in intraday activity between TIPS and nominal securities is that there is virtually no overnight trading of TIPS, with less than 0.1% of TIPS trading volume occurring outside of New York trading hours. In contrast, analyses of the nominal market find that about 5% of interdealer trading occurs outside New York hours (Fleming (1997), Fleming and Mizrach (2008)). The dearth of overnight trading is consistent with the hypothesis that TIPS trading is driven more by lower-frequency institutional trading demands as opposed to higher-frequency hedging and speculative demands, and also with the evidence that foreign investors purchase TIPS to a much lesser degree than nominal securities.

Bid-ask spreads for TIPS are at their widest at the beginning of the trading day when trading is sparse, narrow sharply as trading volume picks up, and then widen again at the end of the day as trading tapers off (Chart 2D). Increases in the spread at 8:30 and 10:00 a.m. correspond to increases in price volatility (Chart 2E), which are likely explained by the release of macroeconomic announcements at those times. The pattern of bid-ask spreads is similar to that observed for nominal Treasury securities (Fleming and Remolona (1999)). The volatility pattern is also similar to that in the nominal market, albeit with less pronounced peaks in volatility at 8:30 and 10:00 a.m. (Fleming (1997), Fleming and Remolona (1999)).

The intraday pattern of market prevalence for TIPS is also consistent with what one might expect given the pattern of trading activity (Chart 2F). That is, a two-sided market is least likely to occur at the beginning and end of the trading day, when trading activity is light.

D. Announcement Effects at a Daily Level

We first analyze the effects of announcements on trading activity at a daily level. At a daily frequency, announcement effects are easiest to discern for trading activity as opposed to price volatility or bid-ask spreads because such announcements have larger, more persistent effects on trading activity (Fleming and Remolona (1999), Balduzzi, Elton, and Green (2001)).

The particular announcements we consider are the consumer price index (CPI), employment report, Federal Open Market Committee (FOMC), and TIPS auction results. The employment report is widely found to be the most important scheduled macroeconomic announcement in the nominal market (Ederington and Lee (1993), Fleming and Remolona (1997), Bollerslev, Cai, and Song (2000), Balduzzi, Elton, and Green (2001), and Huang, Cai, and Wang (2002)). FOMC announcements are also quite important (Kuttner (2001), Gurkaynak, Sack, and Swanson (2005) and Fleming and Piazzesi (2005)). CPI announcements are also influential, but may be particularly so for TIPS given that cash flows on TIPS are tied to this release. Auction results are often not included in announcement studies, but have been found to be associated with some of the sharpest price moves in the TIPS market (Dupont and Sack (1999)).

We analyze announcement effects on trading activity by regressing daily trading volume and daily trading frequency on dummy variables for our various announcements.[14] The results show that TIPS trading activity is nearly twice as high on TIPS auction days as on other days and also significantly higher on CPI and to a lesser extent FOMC announcement days (Charts 3A and 3B). On TIPS auction days, trading volume thus averages $975 million,

[14] We consider all CPI and employment report announcements in our sample, all TIPS auctions, be they of new securities or reopenings of existing securities, and FOMC announcements after scheduled meetings, but not unscheduled meetings.

vs. $527 million on non-announcement days (days without a TIPS auction or a CPI, employment report, or FOMC announcement). On CPI and FOMC announcement days, it averages $863 and $662 million, respectively. On employment report days, in contrast, volume is insignificantly different from that on non-announcement days. The announcement effects are similar when controlling for the day of the week.[15]

These announcement effects are somewhat different from those found in the nominal market. As noted, the employment report is widely found to be highly important in the nominal market, and to spur significant increases in trading activity (Fleming and Remolona (1997) and Balduzzi, Elton, and Green (2001)), but is found to have little effect on TIPS activity at the daily level. The CPI announcement is also found to elicit increases in activity in the nominal market and large effects for TIPS in particular are not surprising. The modest increases in activity on FOMC days are also consistent with evidence for the nominal market (Fleming and Piazzesi (2005)). The auction results are the most striking, and consistent with the limited evidence available from the nominal market.[16]

E. High-Frequency Analysis of Announcement Effects

A high-frequency analysis allows us to discern the effects of announcements more precisely and thus better ascertain how the market adjusts to announcements. The particular variables we consider, which are commonly examined in announcement studies in the

[15] There are pronounced day-of-week effects in trading activity in the TIPS market, as there are in the nominal market. In particular, trading volume is lowest on Monday, averaging $424 million, highest on Wednesday and Thursday, averaging $615 and $658 million, respectively, with Tuesday and Friday in between, at $552 and $546 million, respectively. These patterns remain when controlling for the announcements examined in this paper.

[16] Fleming and Remolona (1997) and Huang, Cai, and Wang (2002) find an immediate increase in trading activity after announcements of auctions results, but auction announcement effects have not been examined in detail like other announcements. A related literature is concerned with market behavior around auctions (e.g., Nyborg and Sundaresan (1996)), but such literature is not generally concerned with the effects of auctions on outstanding securities.

nominal market, are price volatility, trading frequency, and bid-ask spread. As in nominal market studies, we conduct the analysis by comparing the intraday behavior of these variables on announcement days with the behavior on non-announcement days (defined as days with none of these announcements). Such an analysis allows for a clean examination of announcement effects, controlling for the typical intraday pattern, because the announcements are released at essentially the same time on announcement days. CPI and employment report announcements are released at 8:30 a.m., auctions results are released within a few minutes of the 1:00 p.m. auction close, and FOMC announcements after scheduled meetings are released around 2:15 p.m.

Our findings across announcements are generally consistent with findings in the nominal market. Such studies find that price volatility spikes higher at the time of a major announcement and then remains somewhat higher than usual for some time (e.g., Fleming and Remolona (1999), Balduzzi, Elton, and Green (2001), and Fleming and Piazzesi (2005)). Our price volatility findings are consistent with this for all but the CPI announcement, although the noisiness of our estimates precludes a more precise comparison (Charts 4A, 5A, 6A, and 7A).

The increases in trading activity that occur at the time of announcement are somewhat cleaner and also consistent with findings in the nominal market, whereby trading activity jumps higher right after announcement and then remains higher than usual for some time (Charts 4B, 5B, 6B, and 7B). The announcement that stands out in terms of trading activity is the one for TIPS auction results. In particular, trading activity on TIPS auction days is much higher than usual in the hours preceding the auction close and peaks in the 10-minute interval preceding the 1:00 p.m. auction close. While trading activity for other

announcements is primarily driven by the news in the announcement, trading activity on TIPS auction days is largely driven by positioning in anticipation of the auction.

Lastly, the pattern for bid-ask spreads is also consistent with findings in the nominal market, whereby spreads jump higher at the time of the announcement, but usually revert quickly to normal levels (Charts 4C, 5C, 6C, and 7C). The pattern for TIPS auction results fits this general pattern, but also indicates narrower-than-usual spreads in the hours preceding the auction close, consistent with the higher-than-usual trading activity at that time.

5. Conclusion

Our analysis of the TIPS market identifies several microstructure features also present in the nominal Treasury securities market, but several unique features as well. As in the nominal market, there is a marked difference in trading activity between on-the-run and off-the-run securities, with trading dropping sharply when securities go off the run. In contrast to the nominal market, there is little difference in bid-ask spreads or quoted depths between such securities, but there is a difference in the prevalence of quotes. The results suggest that trading activity and market prevalence are good cross-sectional measures of liquidity in the TIPS market, but that bid-ask spreads and quoted depths are not.

Intraday patterns of trading activity are broadly similar in the TIPS and nominal markets, but TIPS activity peaks somewhat later, likely reflecting differences in the uses and ownership of the securities. Announcement effects are also different, reflecting the types of information most important to the particular securities. The employment report is the most important announcement in the nominal market, but elicits relatively little response in the TIPS market. In contrast, announcements of the consumer price index and TIPS auctions

results precipitate significant increases in TIPS trading activity, reflecting these announcements' particular importance to TIPS valuation.

References

Balduzzi, Pierluigi, Edwin J. Elton, and T. Clifton Green, 2001, "Economic News and Bond Prices: Evidence from the U.S. Treasury Market," *Journal of Financial and Quantitative Analysis* 36, 523-43.

Barclay, Michael J., Terrence Hendershott, and Kenneth Kotz, 2006, "Automation versus Intermediation: Evidence from Treasuries Going Off the Run," *Journal of Finance* 61, 2395-414.

Beechey, Meridith J. and Jonathan H. Wright, 2008, "The High-Frequency Impact of News on Long-Term Yields and Forward Rates: Is it Real?" Working paper.

Bollerslev, Tim, Jun Cai, and Frank M. Song, 2000, "Intraday Periodicity, Long Memory Volatility, and Macroeconomic Announcement Effects in the U.S. Treasury Bond Market," *Journal of Empirical Finance* 7, 37-55.

Boni, Leslie and Chris Leach, 2004, "Expandable Limit Order Markets," *Journal of Financial Markets* 7, 145-85.

Buraschi, Andrea, and Alexei Jiltsov, 2005, "Inflation Risk Premia and the Expectations Hypothesis," *Journal of Financial Economics* 75, 429-90.

Campbell, John Y., and Robert J. Shiller, 1997, "A Scorecard for Indexed Government Debt," in Ben Bernanke and Julio Rotermberg, eds., *NBER Macroeconomics Annual*. Cambridge, MA: MIT Press, 155–97.

D'Amico, Stefania, Don H. Kim, and Min Wei, 2008, "Tips from TIPS: the Informational Content of Treasury Inflation-Protected Security Prices," Finance and Economics Discussion Series 2008-30.

Dupont, Dominique, and Brian Sack, 1999, "The Treasury Securities Market: Overview and Recent Developments," *Federal Reserve Bulletin* 85, 785-806.

Ederington, Louis H., and Jae Ha Lee, 1993, "How Markets Process Information: News Releases and Volatility," *Journal of Finance* 48, 1161-91.

Fabozzi, Frank J., and Michael J. Fleming, 2005, "U.S. Treasury and Agency Securities," in Frank J. Fabozzi, ed., The Handbook of Fixed Income Securities, 7th ed., New York, McGraw Hill.

Fleming, Michael J., 1997, "The Round-the-Clock Market for U.S. Treasury Securities," Federal Reserve Bank of New York *Economic Policy Review* 3 (July), 9-32.

Fleming, Michael J., 2002, "Are Larger Issues More Liquid? Evidence from Bill Reopenings," *Journal of Money, Credit and Banking 34*, 707-35.

Fleming, Michael J., 2003, "Measuring Treasury Market Liquidity," Federal Reserve Bank of New York *Economic Policy Review* 9 (September), 83-108.

Fleming, Michael J., 2007, "Who Buys U.S. Treasury Securities at Auction?" *Current Issues in Economics and Finance* 13, January.

Fleming, Michael J. and Bruce and Mizrach, 2008, "The Microstructure of a U.S. Treasury ECN: The BrokerTec Platform," Working paper, March.

Fleming, Michael J. and Monika Piazzesi, 2005, "Monetary Policy Tick-by-Tick," Working paper, August.

Fleming, Michael J. and Eli M. Remolona, 1997, "What Moves the Bond Market?" Federal Reserve Bank of New York *Economic Policy Review* (December), 31-50.

Fleming, Michael J. and Eli M. Remolona, 1999, "Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information," *Journal of Finance* 54, 1901-15.

Goldreich, David, Bernd Hanke, and Purnendu Nath, 2005, "The Price of Future Liquidity: Time-Varying Liquidity in the U.S. Treasury Market," *Review of Finance* 9, 1-32.

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson, 2005, "Do Actions Speak Louder than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking* 1, 55-93.

Gurkaynak, Refet S., Brian Sack, and Jonathan Wright, 2008, "The TIPS Yield Curve and Inflation Compensation," Finance and Economics Discussion Series 2008-05.

Huang, Roger D., Jun Cai, and Xiaozu Wang, 2002, "Information Based Trading in the Treasury Note Interdealer Broker Market," *Journal of Financial Intermediation* 11, 269-96.

Kuttner, Kenneth, 2001, "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market." *Journal of Monetary Economics* 47, 523-44.

Nyborg, Kjell G. and Suresh Sundaresan, 1996, "Discriminatory versus Uniform Treasury Auctions: Evidence from When-Issued Transactions," *Journal of Financial Economics* 42, 63-104.

Roush, Jennifer E., 2008, "The "Growing Pains" of TIPS Issuance," Finance and Economics Discussion Series 2008-08.

Sack, Brian, and Robert Elsasser, 2004, "Treasury Inflation-Indexed Debt: A Review of the U.S. Experience," Federal Reserve Bank of New York *Economic Policy Review* 10, (May), 47-63.

Table 1 -- Trading Activity by Sector

Sector	Volume	Number of Trades	Trade Size
5 year	109.6	11.2	9.5
10 year	402.7	46.4	8.8
20 year	36.4	7.5	4.7
30 year	13.4	4.3	3.2
Total	562.1	69.4	7.1

Note: The table reports average daily outright trading activity in TIPS over the March 4, 2005 to March 27, 2008 period. Sector buckets are defined according to securities' time to maturity at issuance. Volume and trade size are in millions of dollars, par value.

Table 2 -- Trading Activity by Time to Maturity

Time to Maturity	Volume	Number of Trades	Trade Size
0-5 years	314.4	31.4	9.8
5-10 years	198.0	26.2	7.5
>10 years	49.8	11.8	4.2
Total	562.1	69.4	7.1

Note: The table reports average daily outright trading activity in TIPS over the March 4, 2005 to March 27, 2008 period. The 0-5 year bracket includes when-issued trading of 5-year notes and the 5-10 year bracket includes when-issued trading of 10-year notes. Volume and trade size are in millions of dollars, par value.

Table 3 -- Trading Activity by On-the-Run/Off-the-Run Status

Panel A: On-the-Run Securities			
Sector	Volume	Number of Trades	Trade Size
5-year	86.6	9.1	9.3
10-year	136.3	18.2	7.2
20-year	29.7	6.2	4.6

Panel B: Off-the-Run Securities			
Sector	Volume	Number of Trades	Trade Size
5-year	27.2	2.1	10.9
10-year	21.9	2.4	9.0
20-year	6.4	1.3	5.3

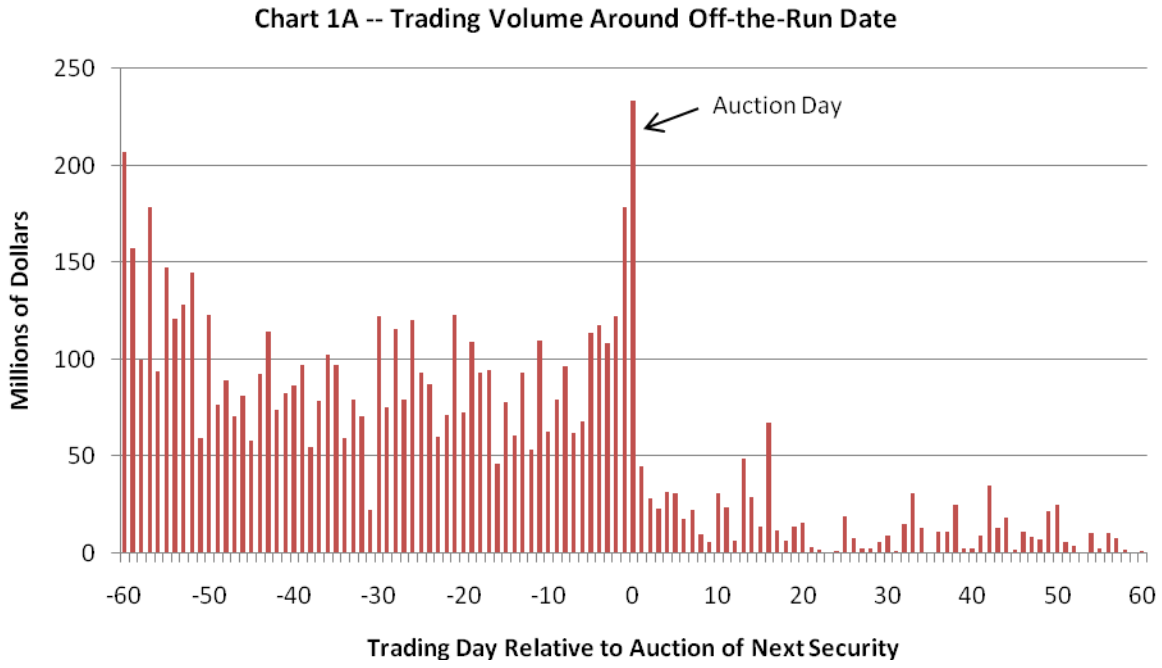
Note: The table reports average daily outright trading activity in on-the-run and off-the-run TIPS over the March 4, 2005 to March 27, 2008 period. Off-the-run averages are *per-security*, and not aggregated across securities. Volume and trade size are in millions of dollars, par value.

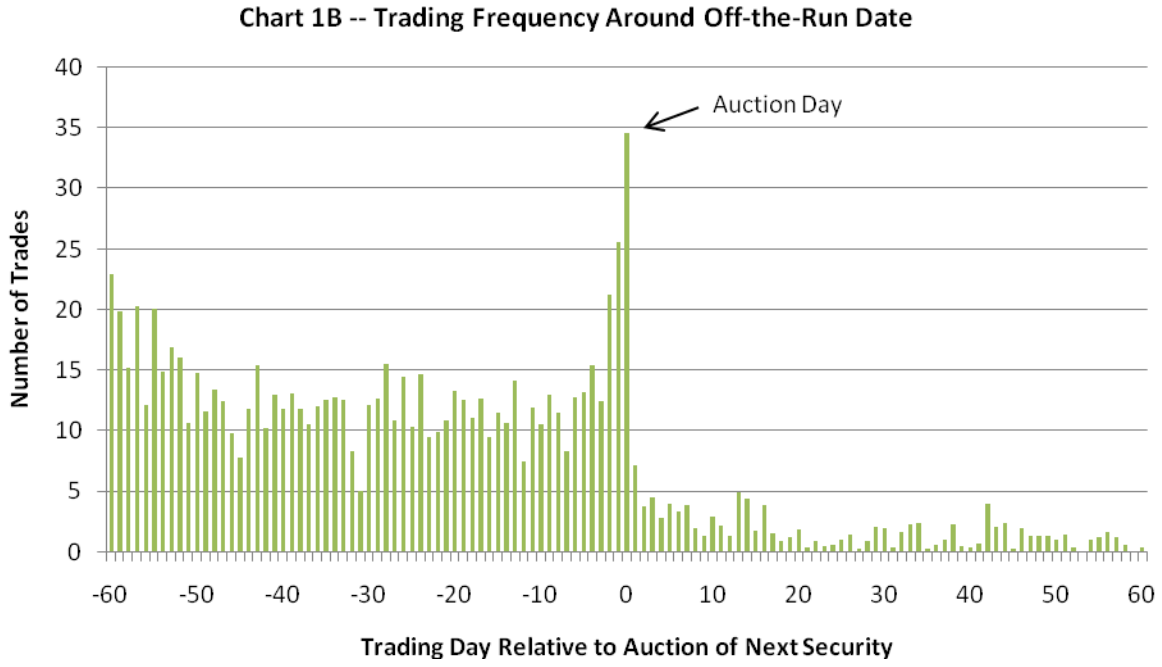
Table 4 -- Quote Measures by On-the-Run/Off-the-Run Status and Sector

Panel A: On-the-Run Securities			
Sector	Bid-Ask Spread	Quote Size	Market Prevalence
5-year	2.4	1.3	42.2
10-year	2.9	1.3	59.7
20-year	6.8	1.1	27.4

Panel B: Off-the-Run Securities			
Sector	Bid-Ask Spread	Quote Size	Market Prevalence
5-year	2.5	1.2	19.4
10-year	2.6	1.3	14.8
20-year	7.0	1.1	7.7

Note: The table reports average daily quote statistics in TIPS over the March 4, 2005 to March 27, 2008 period. The market prevalence measure gauges the percent of time (on trading days between 7:30 a.m. and 5:30 p.m.) that there is a two-sided market in a security (that is, both a bid quote and an offer quote). Bid-ask spreads are in 32nds of a point (a point equals one percent of par) and quote sizes are in millions of dollars, par value.





Note: The charts plots average trading activity of 10 TIPS (two 5-year notes, five 10-year notes, and three 20-year bonds) that went off-the-run during the sample period by trading day relative to the auction day of the next security within each security's sector.

Chart 2A -- Intraday Trading Volume of On-the-Run 10-Year Note

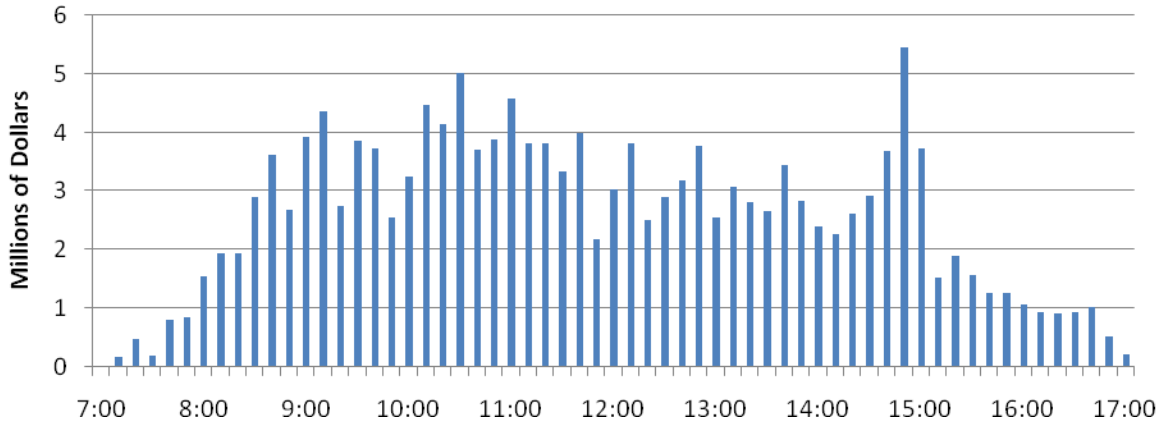


Chart 2B -- Intraday Trading Frequency of On-the-Run 10-Year Note

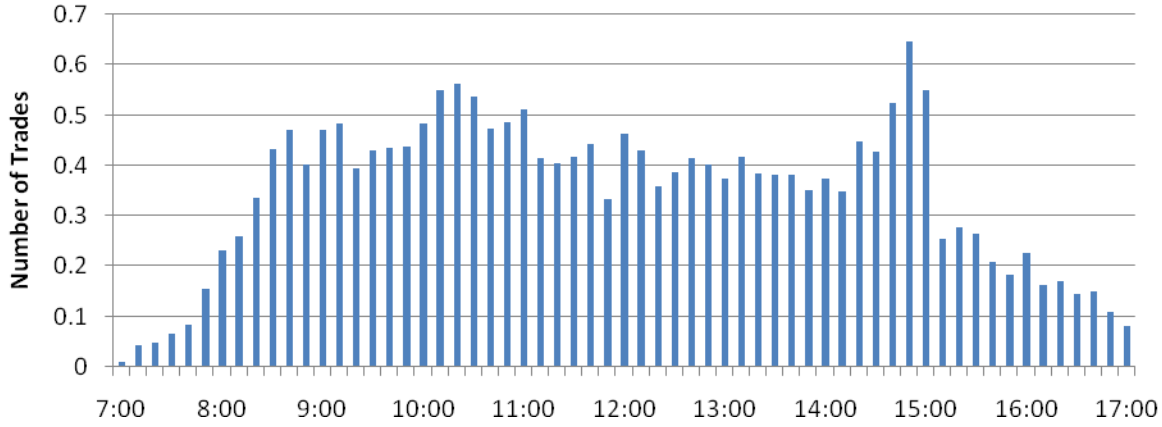


Chart 2C -- Intraday Trade Size of On-the-Run 10-Year Note

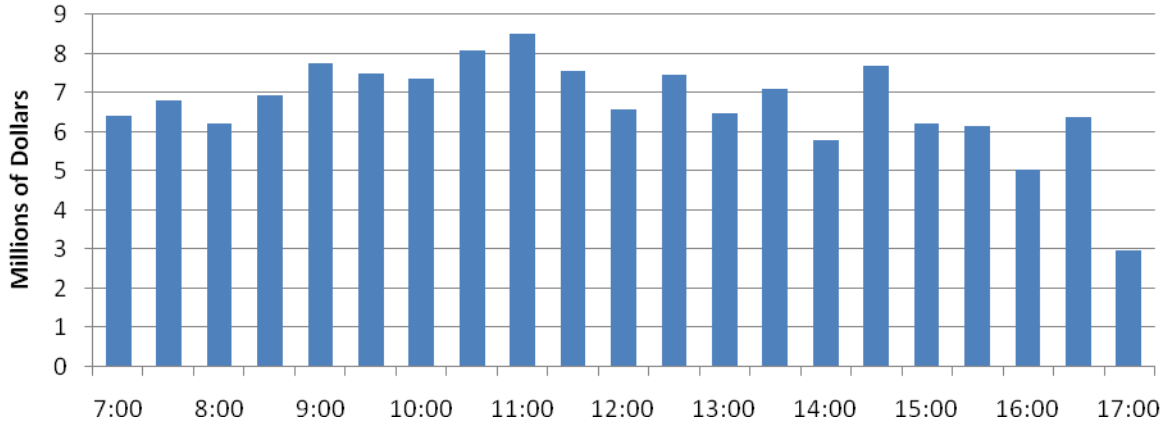


Chart 2D -- Intraday Bid-Ask Spread of On-the-Run 10-Year Note

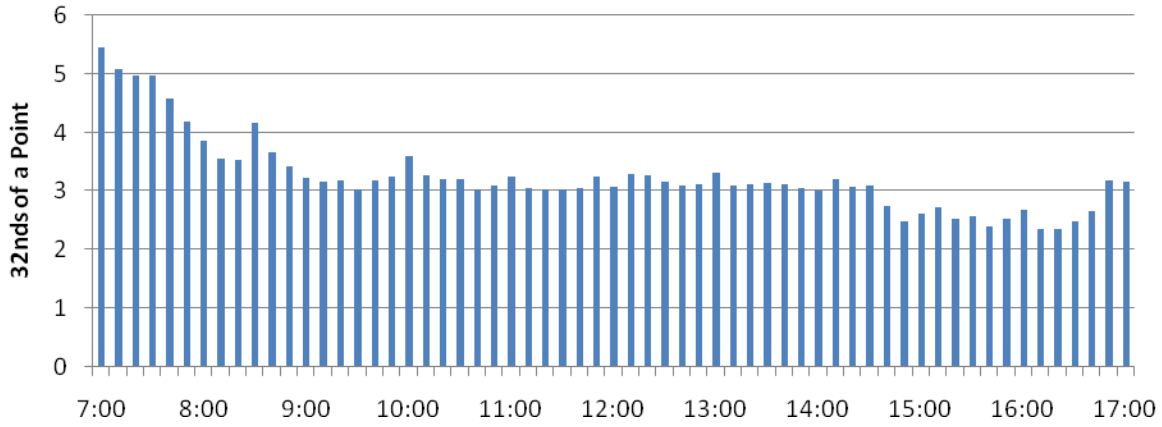


Chart 2E -- Intraday Price Volatility of On-the-Run 10-Year Note

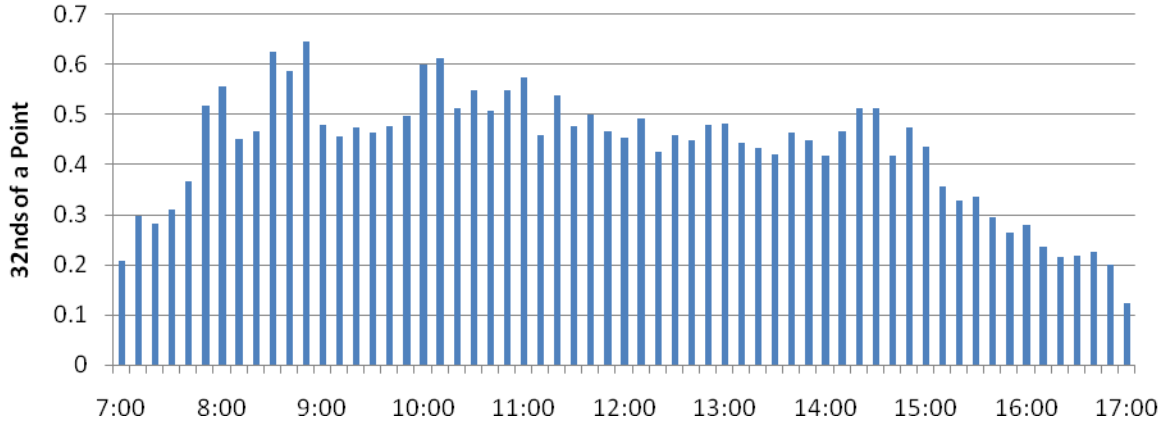
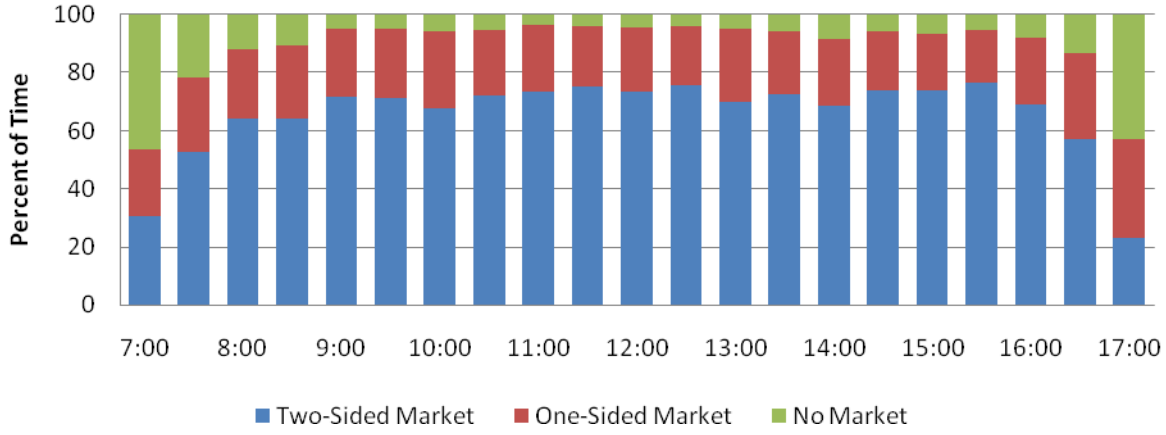


Chart 2F -- Intraday Market Prevalence of On-the-Run 10-Year Note



Notes: The charts plot intraday patterns of trading activity, liquidity, and price volatility for the on-the-run 10-year Treasury inflation-protected security. Price volatility gauges the average absolute price change in each 10-minute interval. Times noted are interval start times.

Chart 3A -- Trading Volume on Announcement and Nonannouncement Days

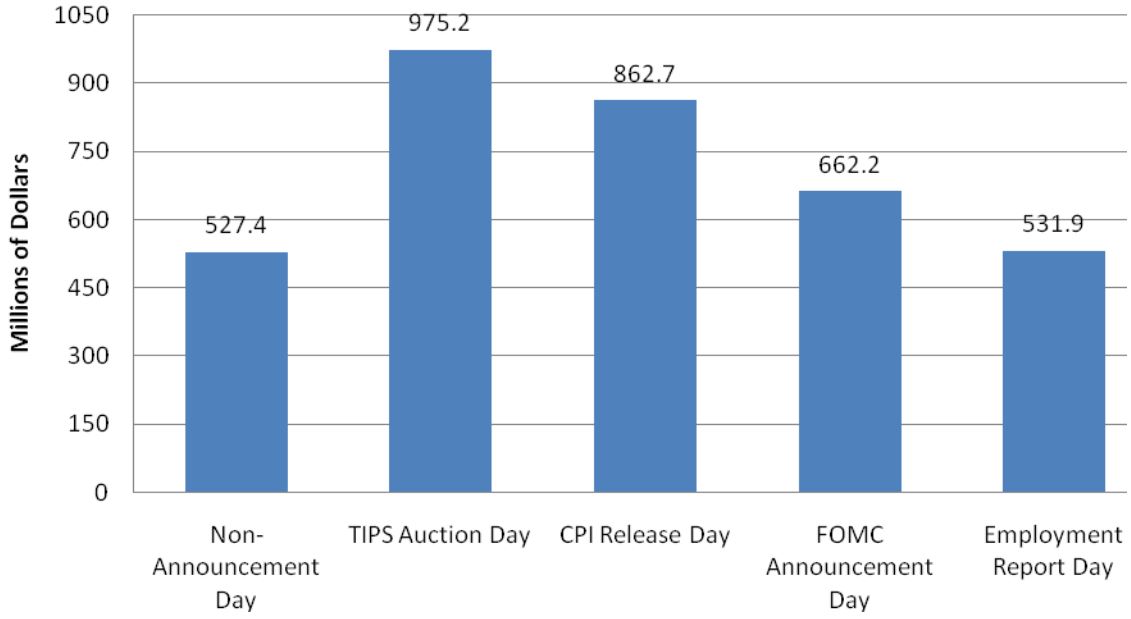
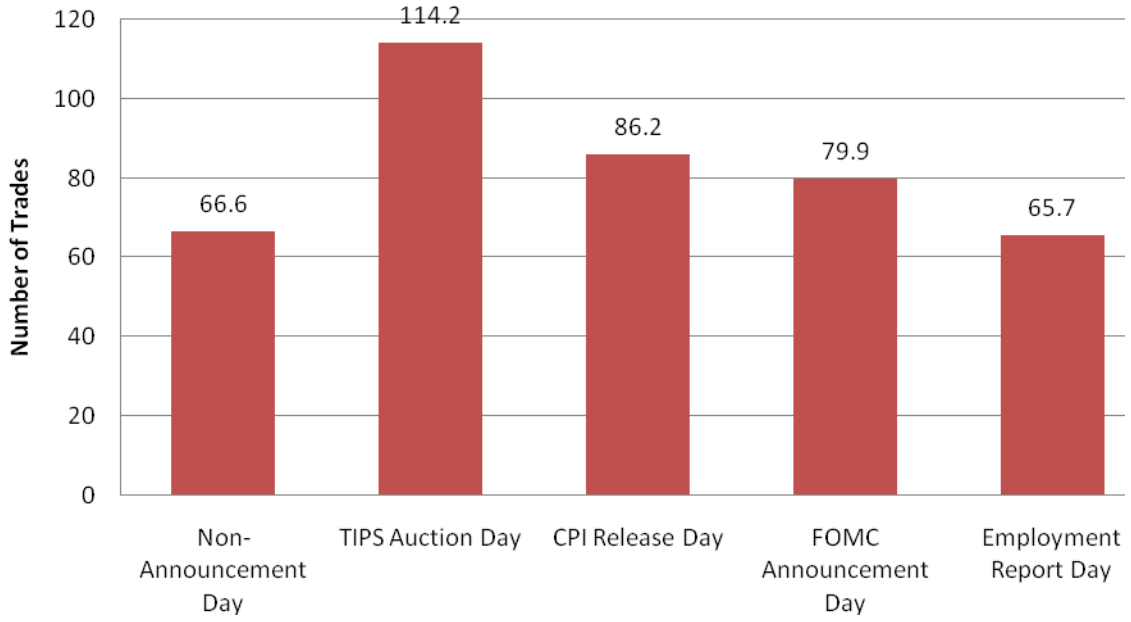


Chart 3B -- Trading Frequency on Announcement and Nonannouncement Days



Note: The charts plot average trading activity in TIPS on TIPS auction days, CPI release days, FOMC announcement days, employment report days, and non-announcement days (days without any of the aforementioned announcements).

Chart 4A -- Intraday Price Volatility on CPI and non-CPI Days

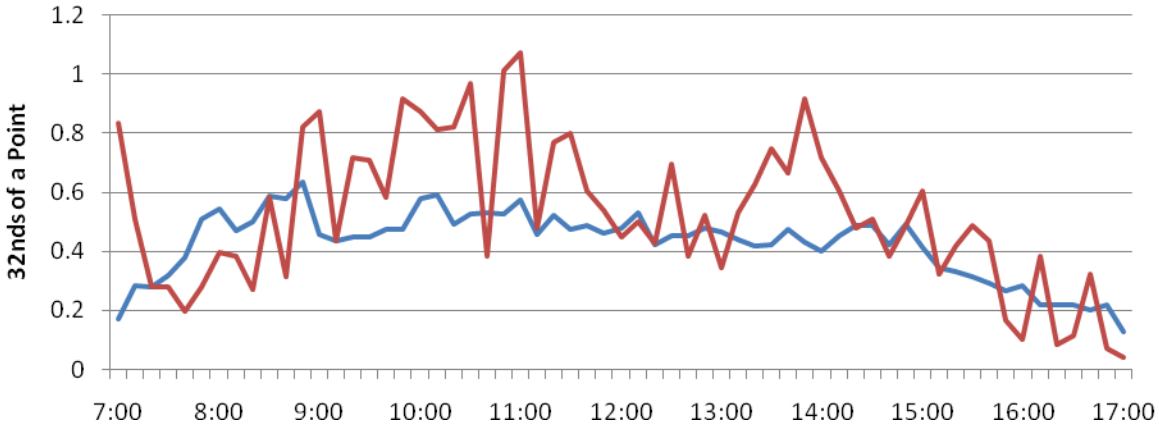


Chart 4B -- Intraday Trading Frequency on CPI and non-CPI Days

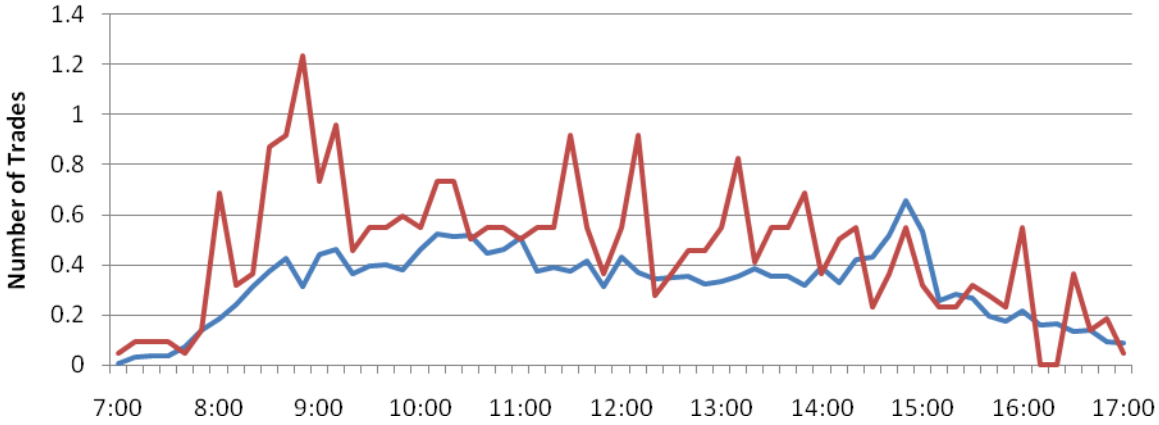
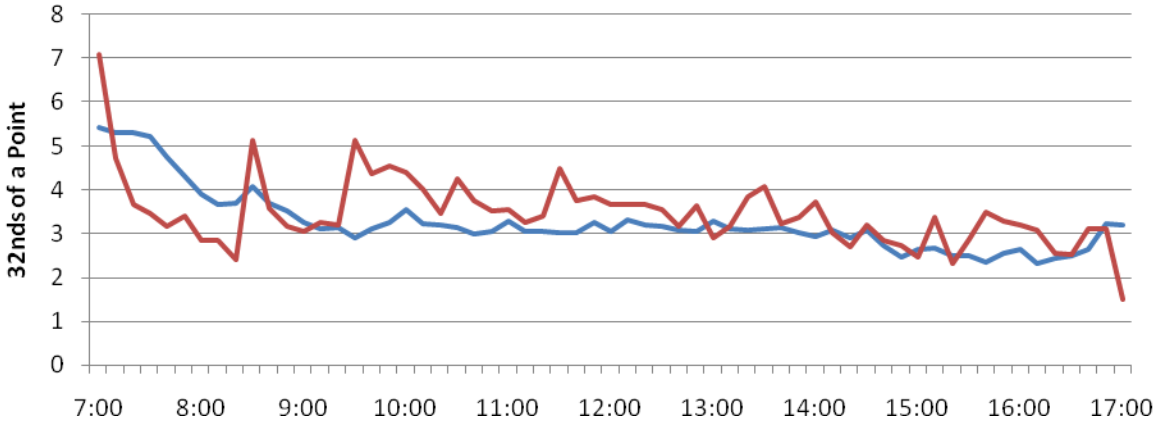


Chart 4C -- Intraday Bid-Ask Spread on CPI and non-CPI Days



Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for CPI announcement days (in red) and non-announcement days (in blue). Times noted are interval start times.

Chart 5A -- Intraday Price Volatility on Emp. Rep. and Non-Emp. Rep. Days

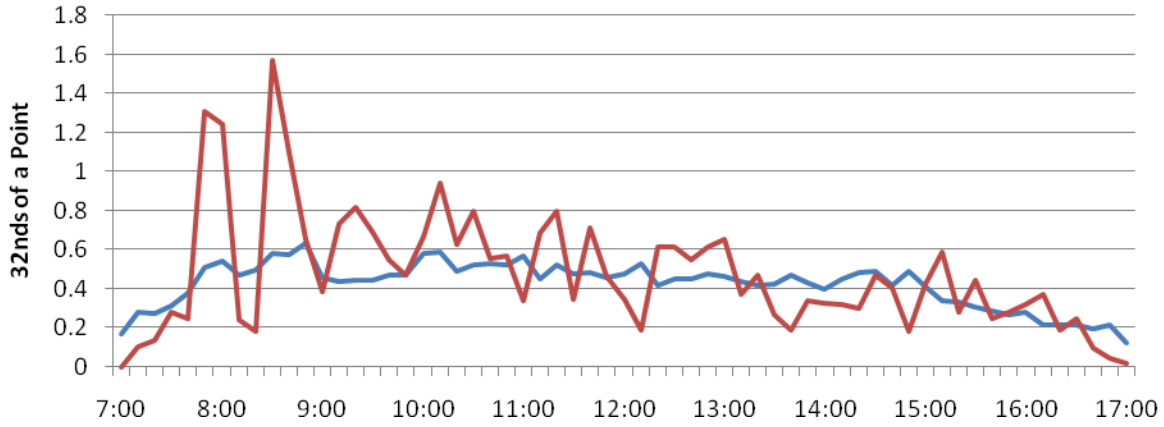


Chart 5B -- Intraday Trading Frequency on Emp. Rep. and Non-Emp. Rep. Days

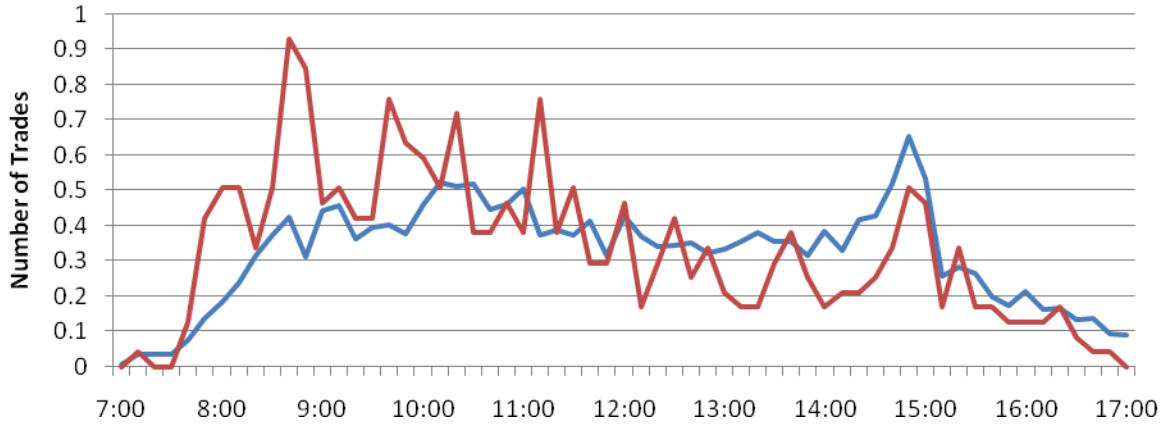
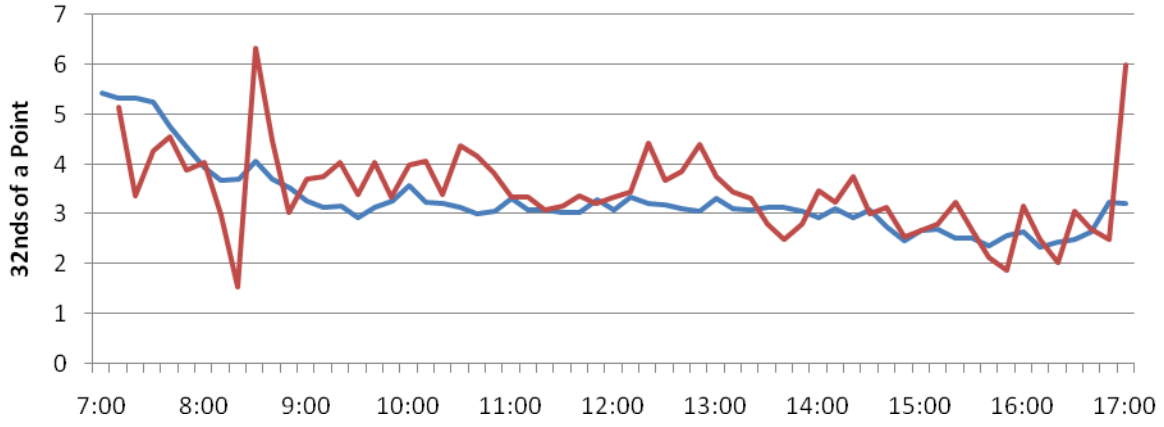


Chart 5C -- Intraday Bid-Ask Spread on Emp. Rep. and Non-Emp. Rep. Days



Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for employment report days (in red) and non-announcement days (in blue). Times noted are interval start times.

Chart 6A -- Intraday Price Volatility on FOMC and non-FOMC Days

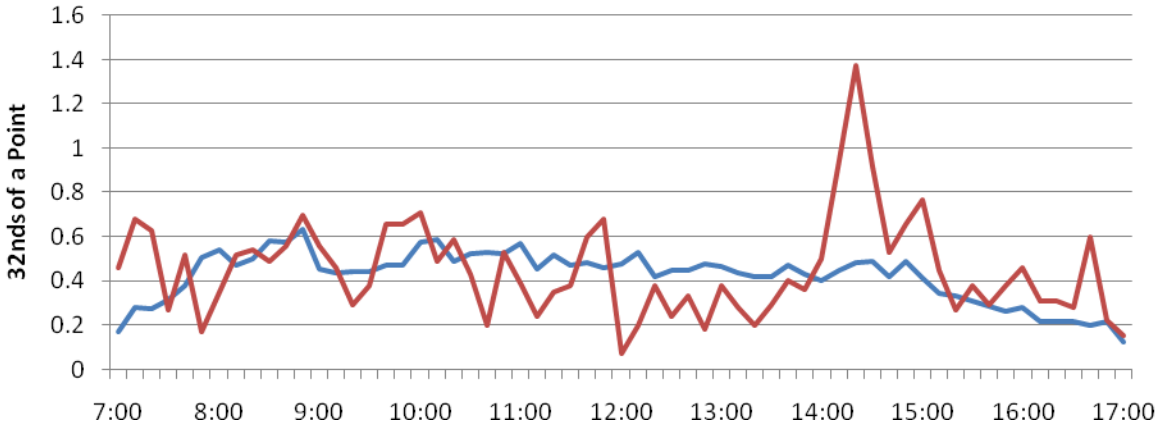


Chart 6B -- Intraday Trading Frequency on FOMC and non-FOMC Days

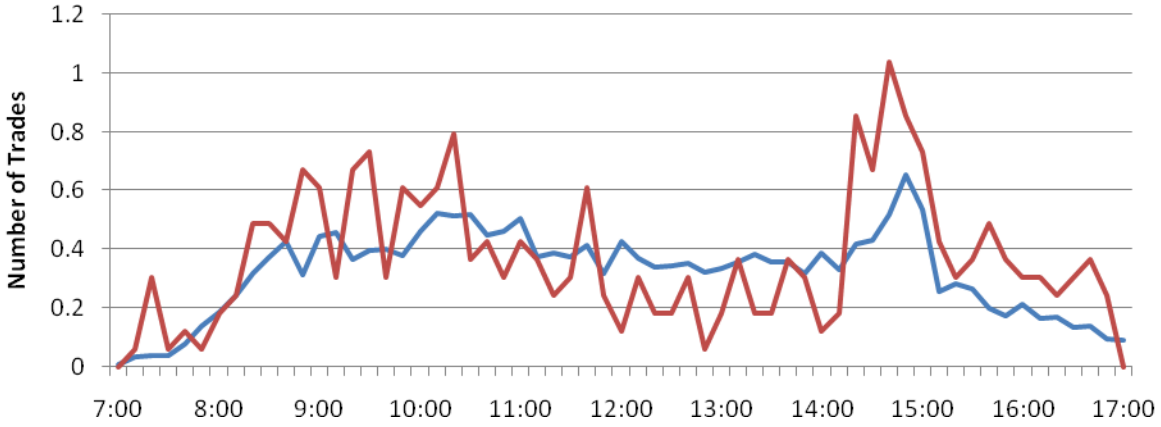
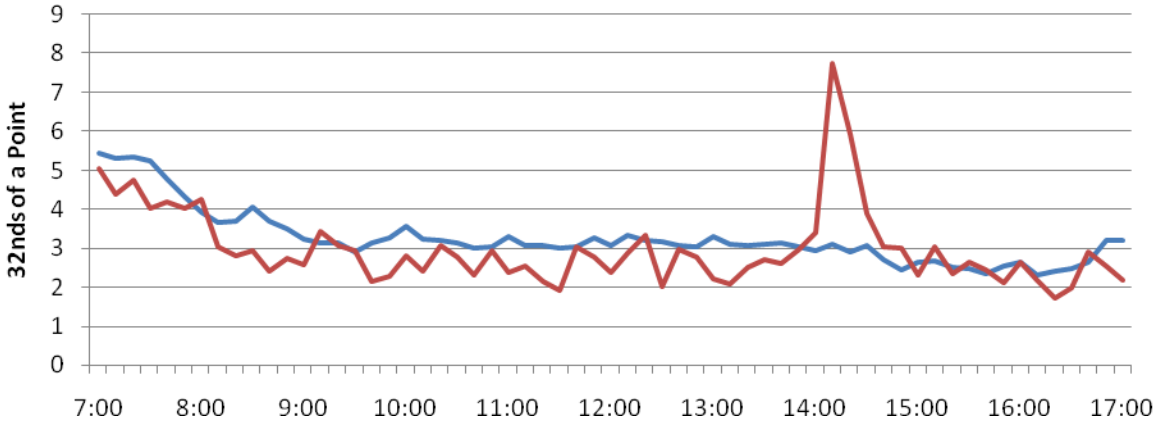


Chart 6C -- Intraday Bid-Ask Spread on FOMC and non-FOMC Days



Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for FOMC announcement days (in red) and non-announcement days (in blue). Times noted are interval start times.

Chart 7A -- Intraday Price Volatility on Auction and Non-AuctionDays

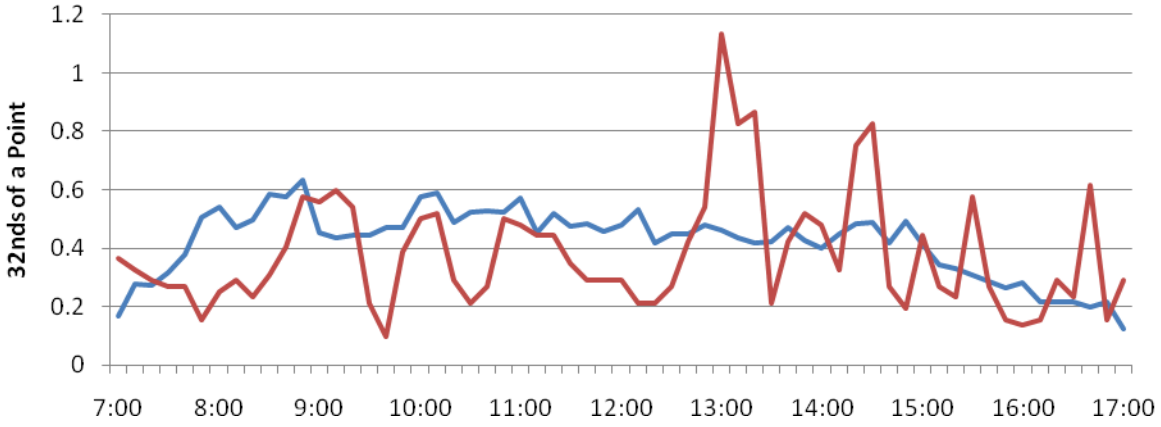


Chart 7B -- Intraday Trading Frequency on Auction and Non-Auction Days

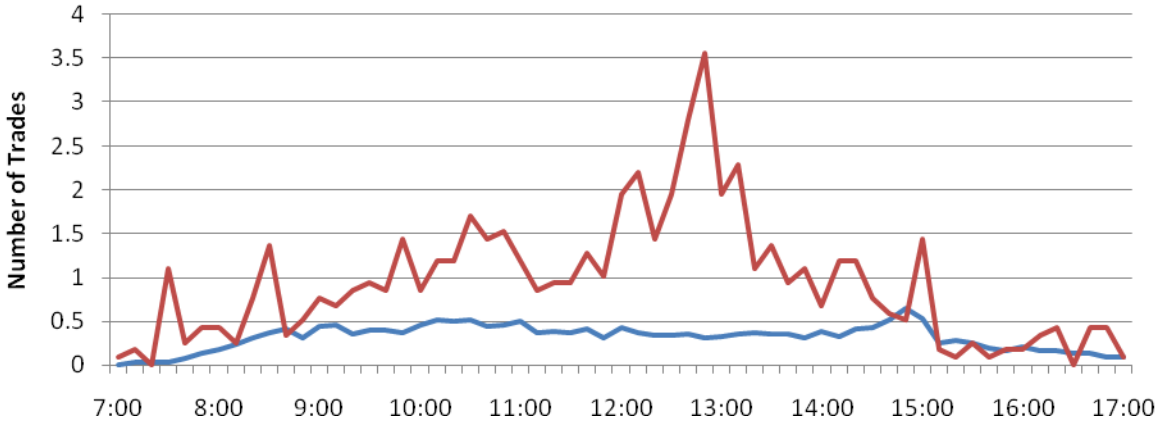
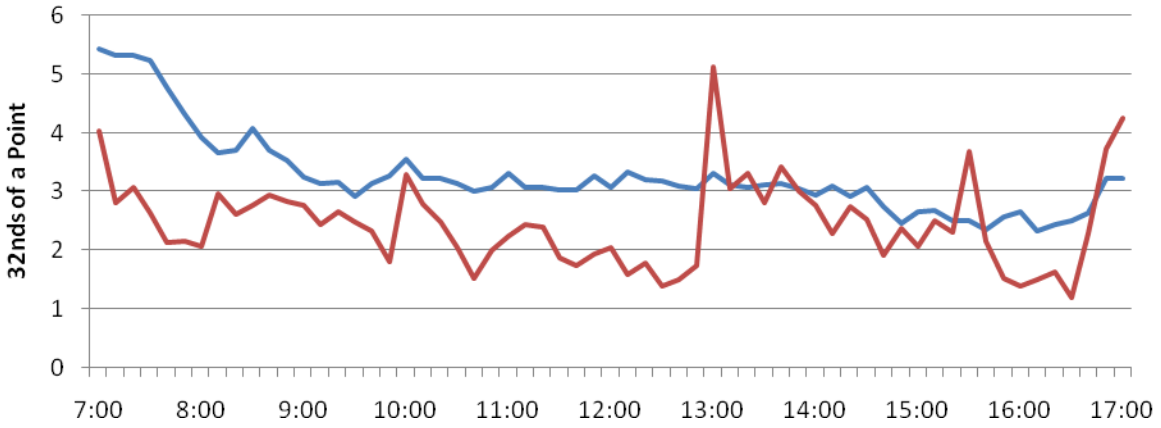


Chart 7C -- Intraday Bid-Ask Spread on Auction and Non-Auction Days



Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for TIPS auction days (in red) and non-announcement days (in blue). Times noted are interval start times.