



Joint Staff Report:

THE U.S. TREASURY MARKET ON OCTOBER 15, 2014

U.S. Department of the Treasury

Board of Governors of the Federal Reserve System

Federal Reserve Bank of New York

U.S. Securities and Exchange Commission

U.S. Commodity Futures Trading Commission

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This is a report of staff findings from the U.S. Department of the Treasury, the Board of Governors of the Federal Reserve System, the Federal Reserve Bank of New York, the U.S. Securities and Exchange Commission, and the U.S. Commodity Futures Trading Commission. The report represents only the views of staff, and the organizations listed above have expressed no view regarding the analysis, findings, or conclusions contained herein.

Executive Summary

The U.S. Treasury market is the deepest and most liquid government securities market in the world. It plays a critical and unique role in the global economy, serving as the primary means of financing the U.S. federal government, a significant investment instrument and hedging vehicle for global investors, a risk-free benchmark for other financial instruments, and an important market for the Federal Reserve's implementation of monetary policy.

On October 15, 2014 ("October 15"), the market for U.S. Treasury securities, futures, and other closely related financial markets experienced an unusually high level of volatility and a very rapid round-trip in prices. Although trading volumes were high and the market continued to function, liquidity conditions became significantly strained. The yield on the benchmark 10-year Treasury security, a useful gauge for the price moves in other, related instruments that day, experienced a 37-basis-point trading range, only to close 6 basis points below its opening level. Intraday changes of greater magnitude have been seen on only three occasions since 1998 and, unlike October 15, all were driven by significant policy announcements. Moreover, in the narrow window between 9:33 and 9:45 a.m. ET, yields exhibited a significant round-trip without a clear cause, with the 10-year Treasury yield experiencing a 16-basis-point drop and then rebound. For such significant volatility and a large round-trip in prices to occur in so short a time with no obvious catalyst is unprecedented in the recent history of the Treasury market.

The abrupt occurrence of such significant and unexplained volatility—particularly in the narrow "event window" starting at 9:33 a.m. ET—calls for a deeper analysis of the conditions that contributed to the events of October 15 and the structure of this important market. This report has been prepared by the staff of the U.S. Department of the Treasury (Treasury), the Board of Governors of the Federal Reserve System (Board), the Federal Reserve Bank of New York (FRBNY), the U.S. Securities and Exchange Commission (SEC) and the U.S. Commodity

Futures Trading Commission (CFTC).¹ It summarizes a set of preliminary findings on October 15, which are based in part on transaction-level, non-public data that staff obtained from the primary locations for price discovery in the Treasury market.² It also describes important characteristics of the current structure of the Treasury market and proposes a series of next steps, including continued analysis of the events of October 15. Because analysis is ongoing and the data are an incomplete snapshot of the U.S. interest rate complex, the findings presented are necessarily preliminary and limited in scope. Nonetheless, the analysis provides information useful in understanding the market conditions and the movements in prices on October 15, and it will serve as a foundation for future work in the study of Treasury market structure and functioning.

Section 1 of the report provides an overview of the U.S. Treasury market, liquidity, applicable regulations, and the data used in the report. For the purpose of this report, the U.S. Treasury market comprises the secondary market trading of cash Treasury securities as well as the futures and options on Treasury securities. Prices are tightly linked across these markets, and linked as well to activity in related markets such as short-term U.S. interest rate futures and U.S. interest rate swaps. Treasury securities are traded over the counter, and trades are executed by voice or on electronic trading platforms within the regulatory framework established by the Government Securities Act (GSA) of 1986, as amended.³ Futures are traded on regulated futures exchanges and are transacted within the regulatory framework established by the Commodity Exchange Act. The report relies on participant-level transaction data from the most liquid parts of the Treasury market, including that for benchmark securities (the “cash” market) and futures (the “futures” market).

¹ The Treasury, SEC, and federal bank regulators, including the Comptroller of the Currency, Board, and the Federal Deposit Insurance Corporation, regulate different aspects of the cash Treasury market and many of its participants, while the CFTC regulates the futures markets, including the Treasury futures markets, and many of its participants.

² In accordance with Section 8 of the Commodity Exchange Act, codified at 7 U.S.C. § 12, this report does not publish data or information that would separately disclose individual business transactions or market positions, trade secrets, or names of customers. All non-public data and information presented in this report has been anonymized and aggregated.

³ See Public Law 99-571, October 28, 1986 and Public Law 103-202, December 17, 1993.

Section 2 of the report explores the events of October 15, including the two defining traits of the day—the unusually high volatility and round-trip in prices despite the lack of an obvious driver, and the strains in liquidity conditions especially during the event window. As described further in the report, the 37-basis-point trading range in the 10-year Treasury security on October 15 was both unusual and of historic size. On the three occasions when intraday moves were greater than 37 basis points, important news was released that significantly influenced the public’s expectations for monetary policy. By contrast, the only notable news on October 15 was the release of somewhat weaker-than-expected U.S. retail sales data at 8:30 a.m. ET. While the data appeared to prompt the initial decline in interest rates, the reaction was significantly larger than would have been expected given the modest surprise in the data. Moreover, the retail sales data do little to explain the fact that large price movements occurred more than an hour after the release.

Liquidity conditions in the Treasury market were also atypical on October 15. While the term “liquidity” may be subject to various uses and interpretations, for the purpose of this report, it might be most simply defined as the cost associated with executing a trade. Academics and practitioners have often used simple price and quantity metrics to describe this cost, but they have also combined that information to construct more sophisticated and comprehensive ways of measuring the cost of trading. On October 15, both simple and complex measures showed signs of significant deterioration. For example, the dollar amount of standing quotes in the central limit order books (CLOBs) on cash and futures trading platforms—a measure of the quantity of liquidity that is commonly referred to as “market depth”—fell dramatically in the hour before the event window. Measures of transaction costs also showed signs of significant deterioration. Despite these changes, trading volumes reached record highs, trading took place in a continuous manner during the event window and throughout the day, and prices for U.S. Treasury securities and futures remained closely linked.

Section 2 also discusses the market environment in the days and weeks preceding October 15, which may have contributed to the general level of volatility on the day but is an unlikely explanation for the dynamics observed in the event window. More specifically, growth and deflation risks in the Eurozone, and the fact that the European Central Bank’s response was as yet unclear, had generated considerable uncertainty among of investors going into the day—a

sentiment reportedly exacerbated by the alleged tone of the annual IMF/World Bank meetings the prior weekend. Additionally, there was an unwind of “short” positions on U.S. interest rates ahead of and on October 15. Such “short” positions were predicated on an anticipated rise in interest rates, and had become particularly popular among investors employing leverage, particularly in shorter-term interest rate futures contracts. But as interest rates began to move lower in September and early October, leveraged funds unwound these short positions by taking on offsetting long positions. While much of the unwind took place in the two weeks ahead of October 15, the moves on October 15 were among the most significant in terms of their day-to-day change. These position changes were most notable in shorter-duration rate instruments, but likely had the effect of putting further downward pressure on yields across the Treasury curve.

Section 3 of the report discusses the key findings from the analysis of participant-level transaction data, with a particular focus on the period leading up to and including the most volatile period of the day, the 9:33 to 9:45 a.m. ET event window. While no single cause is apparent in the data, the analysis thus far does point to a number of findings which, in aggregate, help explain the conditions that likely contributed to the volatility.

- An analysis of transactions shows that, on average, the types of firms participating in trading on October 15 did so in similar proportions to other days in the sample data. Principal trading firms (PTFs) represented more than half of traded volume, followed by bank-dealers. Both bank-dealers and PTFs continued to transact during the event window, and the share of PTF trading increased significantly.
- The trading volume of PTFs and bank-dealers in the cash and futures markets is highly concentrated in the most active firms. In the cash market, for instance, the 10 most active PTFs conducted more than 90 percent of the trading activity of all PTFs on October 15, while the 10 most active bank-dealers accounted for nearly 80 percent of the trading activity of all banks. The concentration findings were generally similar for the futures market.
- A review of position changes shows sizable changes in net positions by different types of participants following the retail sales data release. However, during the event window, only modest changes in net positions occurred, suggesting that changes in global risk sentiment and associated investor positions may help to explain a portion of the price

movements during the day, but do not appear to explain the round-trip in prices during the event window itself.

- During the event window, an imbalance between the volume of buyer-initiated trades and the volume of seller-initiated trades is observed, with more buyer-initiated trades as prices rise in the first part of the window, and more seller-initiated trades as prices fall in the second part of the event window. Such imbalances are common during periods of significant directional market moves. Both bank-dealers and PTFs initiate these liquidity-removing trades, though PTFs account for the largest share. At the same time, strong evidence suggests that PTFs, as a group, also remained engaged as liquidity providers throughout the event window, implying that more than one type of PTF strategy was at work.
- Several large transactions—though not unusual in size relative to other sample days—occurred between the retail sales release and the start of the event window. Some coincided with a significant reduction in market bid and offer depth—both during this interval and at the start of the event window itself. But during the event window, the analysis does not suggest a direct causal relationship between the volatility and one or more large transactions, orders, or substantial position change.
- The significant reduction in market depth following the retail sales data release appears to be the result of both the high volume of transactions and bank-dealers and PTFs changing their participation in the cash and futures order books. During the event window, bank-dealers tended to widen their bid-ask spreads, and for a period of time provided no, or very few, offers in the order book in the cash Treasury market. At the same time, PTFs tended to reduce the quantity of orders they supplied, and account for the largest share of the order book reduction, but maintained tight bid-ask spreads. Both sets of actions prompted the visible depth in the cash and futures order books to decline at the top price levels.
- The time required by the futures exchange to process incoming orders, or “latency,” increased just prior to the start of the event window. This latency was associated with a significant increase in message traffic—in this case elevated due to order cancellations. Transaction data also show a higher incidence of “self-trading” during the event window. For the purpose of this report, self-trading is defined as a transaction in which the same

entity takes both sides of the trade so that no change in beneficial ownership results. Although self-trading represented a non-trivial portion of volume, this activity also appears on days other than October 15 in the sample. Any causal connection between the unusually high level of cancellations or the self-trading and the event window at this time remains unknown.

In sum, record trade volumes, a decline in order book depth, changes in order flow and liquidity provision, and notable and unusual market activity together provide important insight into the factors that may have contributed to the heightened volatility, decreased liquidity, and round-trip in prices on October 15.

To better understand the context for the conditions, the report in **Section 4** reviews broad changes to the structure of the Treasury market over the past two decades. In particular, the growth in high-speed electronic trading has contributed to the growing presence of PTFs in Treasury markets, with these firms now accounting for the majority of trading and providing the vast majority of market depth. By contrast, bank-dealer activity in the “interdealer” market now accounts for well under half of the trading and quoting activity, a significantly smaller share of market intermediation than in the past, perhaps reflecting increasing costs and competitive pressures associated with market-making activities in the Treasury market. These changes in intermediation and the provision of liquidity have coincided with significant growth in the U.S. fixed-income market and potential changes in the demand for liquidity by many investors.

By many metrics, the liquidity and efficiency of trading in the Treasury market are as robust as they have ever been. For example, bid-ask spreads have remained steady at very low historical levels. But the changes in market structure also raise questions about evolving risks, such as whether an improvement in average liquidity conditions may come at the cost of rare but severe bouts of volatility that coincide with significant strains in liquidity. The changing nature of liquidity also suggests that the way it is measured may need to be enhanced in order to obtain a more meaningful understanding of the state of the market.

Finally, as explained in **Section 5**, the events of October 15 underscore the importance of efforts by the official and private sectors to understand more fully the implications of the

evolving Treasury market structure for liquidity, trading and risk management practices, data access, and monitoring and surveillance. To further such efforts, the report suggests next steps in four areas:

- further study of the evolution of the U.S. Treasury market and its implications for market structure and liquidity,
- continued monitoring of trading and risk management practices across the U.S. Treasury market and a review of the current regulatory requirements applicable to the government securities market and its participants,
- an assessment of the data available to the public and to the official sectors on U.S. Treasury cash securities markets, and
- continued efforts to strengthen monitoring and surveillance and to promote interagency coordination related to the trading across the U.S. Treasury market.

Section 1: Background on Treasury Market Liquidity, Regulation, and Data

Liquidity and the Treasury Market

The U.S. Treasury market is the deepest and most liquid government securities market in the world. This superior liquidity is important for a number of reasons: it accrues lower cost of borrowing to Treasury thus benefitting taxpayers, it allows U.S. Treasury securities to act as a reliable interest rate benchmark for a wide range of private market transactions, it provides a reliable means for market participants to transfer interest rate risk on a substantial scale, and it is supportive of the implementation of U.S. monetary policy.

While the term “liquidity” can be subject to various uses and interpretations, for the purposes of this report it might be most simply defined as the cost associated with executing a trade. Academics and practitioners have used both simple price and quantity metrics to describe this cost, along with more sophisticated methods that combine price and quantity information to measure the cost of trading more comprehensively. Another manner in which liquidity might be viewed is across an immediacy spectrum. Through that lens, liquid markets are those where participants *are able to continuously* transact even if there is little market depth and prices are very responsive to incoming orders to buy or sell securities. In this case, there might be a high cost to transact, but still a continuous ability to change positions.

Either definition—whether centered on cost or immediacy—might be viewed as a relatively narrow form of liquidity on its own. A broader form of market liquidity might require the conditions from both definitions be met: participants can continuously transact, and relatively large transactions have a limited cost associated with them. That is, markets are most liquid when they are both continuous and deep. That said, price volatility and liquidity certainly interact and can be co-dependent.

The U.S. Treasury market enjoys liquidity defined more broadly, with continuous trading and substantial market depth. However, on October 15, specifically in the 12 minute event window, the U.S. Treasury market—while in one sense remaining liquid as participants were able to continuously transact—experienced uncharacteristically shallow market depth. Moreover, the continuous trading in these 12 minutes seemed unrelated to any new information,

leading to questions about the efficiency of price formation in the Treasury market during that time. A higher incidence of such strains in market liquidity could prove harmful to the many critical functions this market enables and serves.

Regulation and the Treasury Market

Several agencies under a range of authorities are responsible for regulating various components of the Treasury market and its participants. The GSA established the regulatory scheme for the regulation of brokers and dealers in the government securities market. Congress, in enacting the GSA, largely relied on the existing federal regulatory structure when assigning registration, examination, reporting, and enforcement responsibilities.⁴ The GSA authorized Treasury to promulgate rules governing transactions in government securities by government securities brokers and dealers. In consultation with the Treasury, the SEC, federal bank regulators, and the Financial Industry Regulatory Authority (FINRA) also have the authority to issue sales practice rules for U.S. government securities secondary market.

Non-bank-affiliated brokers or dealers that solely conduct a business in government securities are required to register with the SEC, but are subject to Treasury rulemaking. General purpose securities brokers or dealers, and financial institutions that conduct a government securities business, are required to file a written notice with their appropriate regulatory agency.

The enforcement and examination authorities in the government securities market reside with the SEC, FINRA or the appropriate bank regulator. In addition, the GSA applies the anti-fraud and anti-manipulation provisions of the federal securities laws to government securities brokers and dealers.⁵

⁴ The history of the GSA made clear that it was intended to address identified weaknesses in the market without creating duplicative requirements, unnecessarily impairing the operation of the market, increasing the costs of financing the public debt or compromising the execution of monetary policy.

⁵ There are, however, several differences in the current regulatory requirements applicable to the government securities market as compared to other U.S. securities, commodities and derivatives markets. For example, FINRA Rule 2010, Standards of Commercial Honor and Principles of Trade, apply to government securities. However, more granular FINRA Rules, such as FINRA Rule 2121 Fair Prices and Commissions, currently does not apply to transactions in government securities. SEC rules applicable to alternative trading systems do not apply to alternative

Treasury and Eurodollar futures (and options on these futures) are regulated by the CFTC, created by Congress in 1974 as an independent agency with the mandate to regulate commodity futures and option markets in the United States. The CFTC's mandate has been renewed and/or expanded multiple times in subsequent years. The CFTC and its predecessor agencies were established to protect market participants and the public from fraud, manipulation, and other abusive practices in the commodity futures and options markets. After the 2008 financial crisis and the subsequent enactment of the Dodd-Frank Wall Street Reform and Consumer Protection Act, the CFTC's mission expanded to include oversight of the swaps markets. The CFTC administers the Commodity Exchange Act (CEA), 7 U.S.C. section 1, et seq. The CEA establishes a comprehensive regulatory structure to oversee futures and swaps trading, including surveillance of the futures and options markets. Surveillance and enforcement authority for these rules sits with the CFTC.

Through regulatory or private sector efforts, securities and futures trading venues have expanded risk management practices over recent years. These risk management tools address concerns or risks related to both automated and manual trading, and aim to mitigate the possibility of activity, or price movement, which may not accurately represent fundamental forces of supply and demand. In the futures markets, these tools include order price and quantity controls (to avoid "fat finger" errors), circuit breakers which trigger during extremely rapid price movements, kill switches, message and order throttles, self-trade prevention tools and post-trade drop copy. Many of these controls can be customized at the level of a firm, desk or trader. Cash market venues have some similar risk mitigation devices, although they currently do not have circuit breaker protocols in place.

Background on Treasury Cash and Futures Markets

trading systems through which only government securities are traded (although such venues may voluntarily adopt such standards). Real time public reporting rules applicable to transactions in other securities and derivatives do not apply to transactions in Treasury securities. Large non-broker and non-dealer participants in the government securities market are not required to register (unlike large swap market participants).

This report analyzes trading activity in the U.S. Treasury market, focusing on order and trade data from venues trading either cash Treasury securities or Treasury futures.

In the cash market, the Treasury issues bills, nominal fixed-rate coupon securities, nominal floating rate securities (FRNs) and inflation indexed securities (TIPS).⁶ The nominal coupon curve is the most active location for secondary market trading, and a large portion of activity takes place in the *most recently issued* nominal coupon securities.⁷ These securities are referred to as “benchmark” issues, as the yields of these securities are used as a reference to price a number of private market transactions. Treasury securities are transacted across multiple secondary market venues: interdealer trading of the benchmark securities occurs mainly on centralized electronic trading platforms utilizing a CLOB protocol such as Broker Tec and eSpeed.⁸ In contrast, dealer-to-customer trading is usually done on a bilateral basis—either through voice or a variety of electronic means. Section 4 of the report contains a more detailed discussion of the structure of the cash market.

Treasury futures across a broad set of maturities are traded at the Chicago Board of Trade (CBOT), a regulated futures exchange, and settle against an underlying Treasury security.⁹ Eurodollar futures, a related short-term USD interest rate futures contract, are listed on the Chicago Mercantile Exchange (CME), and settle against the 3-month LIBOR rate. Both

⁶ Treasury bills are issued at a discount and mature in one year or less. FRNs are issued at an original maturity (currently of 2 years) and have a coupon that adjusts based on 13-week bill auction rates. Nominal coupon securities pay a fixed semi-annual coupon and are currently issued at original maturities of 2-, 3-, 5-, 7-, 10- and 30-years. Finally, TIPS pay a fixed real rate of interest, undergo principal accrual based on realized inflation, and are currently issued at original maturities of 5-, 10- and 30-years.

⁷ Once another security is issued at a given original maturity point it becomes the new benchmark security (or new “on-the-run” security) for that maturity point and the former benchmark security is then said to trade in the “off-the-run” market. Trading of off-the-run securities has always been less active and is not the focus here as price discovery in Treasury markets primarily occurs in the benchmark issues in the cash market and in the futures markets.

⁸ BrokerTec offers a “workup” mechanism that is initiated by a regular order book trade. The workup provides an opportunity for all traders to transact additional quantity on either side of the initial trade at the price of the initiating trade. The workup mechanism on BrokerTec is widely used and represents a majority of BrokerTec trading volume during the event window.

⁹ Product maturities for futures include 2-year, 3-year, 5-year, and 10-year Treasury notes, the 30-year Treasury bond (for underlying bonds of 15 to 25 years maturity), and the ultra-long bond (maturity greater than 25 years).

exchanges are owned by the CME Group, with the vast majority of futures trades occurring on an anonymous CLOB, though larger or more complex trades may happen in the futures pit or off-exchange as blocks. Futures regulations mandate that all trading in a futures contract occur on, or, in the case of blocks, get reported to, the trading platform operated by the futures exchange where the contract is listed. All trades are then reported, on a post-trade basis, through a real-time public ticker. The CFTC, as the futures regulator, receives a transaction audit trail with participant identifiers which aids in ongoing market surveillance and enforcement.

Data and Firm Classification Methods

To analyze the events during and around the event window on October 15, staff obtained access to participant-level transaction data from the major cash trading platforms—BrokerTec and eSpeed—and from the CME.¹⁰ Staff also had access to participant-level order book information. In addition to data on October 15, data for 16 control days were obtained, including four days characterized by considerable volatility, and twelve days of unremarkable volatility. The volatile control days were May 22, 2013, June 19-20, 2013, and June 5, 2014, and the non-volatile control days were April 2-17, 2014. Data from both the cash and futures markets provide price, quantity and timing information, and allow for full reconstructions of trade and order book activity within the focal contracts and benchmark maturities of at least millisecond granularity.

Participant identifiers, at varying levels of granularity, are included in trade and order audit trails in the cash and futures markets. Using these, participants were grouped into several broad categories based on their business model and corporate structure. The firm categories used for futures and cash classification are bank dealer, non-bank dealer, hedge fund, asset manager, and PTFs. Categorizing the firms requires some judgment, particularly given that they sometimes share certain characteristics or may act in multiple capacities. However, the presence of legal

¹⁰ Cash market trade data presented here are from Broker Tec, though eSpeed data was also analyzed. Results for market concentration and participation levels (discussed later in this report) were similar across both platforms.

name identifiers allows for the classification of participants ex-ante by legal status in combination with existing information about trading objectives/motivations, investment horizon and balance sheet capacity.¹¹ Appendix A provides more detail on the classification framework used, and describes some distinct characteristics of the five different types of firms. Importantly, each type of firm employs some level of automated trading, with varied degrees of sensitivity to market speed, and functions as both a liquidity provider and taker, with varied holding periods depending on strategy. Bank dealers, for example, utilize manual trading strategies to a greater extent than other categories, especially in the cash market and when taking liquidity, have higher fill ratios, and transact as agents on behalf of customers. PTFs are uniquely characterized by their almost exclusive use of automated trading, lower fill ratios, and primarily principal trading activity.¹² Nevertheless, the tables in Appendix A provide statistics indicating that activity within a category varies considerably by specific firm. In particular, some bank-dealer and hedge fund trading patterns exhibit characteristics of PTFs, while many smaller PTFs clearly are not trading rapidly.

There are several aspects of the U.S. Treasury and broader U.S. fixed income market that are not represented in this data. For example, cash Treasury market data do not include the large dealer-to-customer market, in which dealers transact—either through voice or electronic means—with their customers. Additionally, data for similarly liquid U.S. interest rate products, such as plain-vanilla interest rate swaps, are not incorporated into this report, nor is data on interest rate options. Nonetheless, the data do capture the most liquid interest rate products traded over a CLOB (namely, benchmark cash securities trading and interest rate futures), which

¹¹ Due to the differing nature and granularity of the available data within the futures and cash markets, it was also necessary to exogenously identify, and match, firms across trading in both markets. Categorizing firms purely by trading behavior, an endogenous classification that is often done in absence of legal name identifiers, can be difficult because it requires the establishment of measurement thresholds in order to separate activity between categories. The entity-level classification scheme employed in the report is in broad agreement with the observed trading activity patterns in the sample and, by implication, is also largely consistent with such endogenous and activity-based classification.

¹² In the report, the term high-frequency trading (HFT) firm is not used given the difficulty in drawing an effective dividing line between those firms that should be included in the category and those that should not.

arguably serve as the primary locations for price discovery in U.S. interest rates.¹³ Certain off-exchange transactions for futures, as well as end-of-day futures positions data, are referenced at specific parts of this analysis.

¹³ A review of the data shows very tight linkages between activity in cash and futures prices at a lead-lag of about 5 milliseconds, strongly suggesting that price discovery and liquidity provision in both markets are tightly linked by automated trading activity. Appendix B provides additional detail on the analysis of such cross-market activity

Section 2: The Events of October 15, 2014

On October 15, 2014, U.S. Treasury cash and futures markets experienced significant volatility amidst record trading volumes, including a rapid round-trip in prices that occurred with no new exogenous information (Figure 2.1). While yields drifted slightly lower in the early morning, more notable price action began at 8:30 am ET with the release of the U.S. retail sales report for the month of September. The data printed slightly weaker than expected: advance sales excluding automobiles declined 0.2 percent, month-over-month, while the median expectation from economists surveyed by Bloomberg suggested a gain of 0.2 percent. As is typically the case with the release of weaker-than-expected economic data, interest rates across the U.S. fixed income complex declined on the news, but the response this time was unusually sharp. Market participants widely noted that the 11 basis point decline in the benchmark 10-year Treasury security yield in the 25 minutes following the release was significantly larger than would have been expected based on the surprise (or unexpected) component of the data alone.¹⁴ Further, trading conditions in fixed income markets began to change. Trading volumes on the futures exchange and electronic cash platforms surged, and the dollar amount of standing quotes in the CLOBs—an important measure of liquidity commonly referred to as “market depth”—fell sharply in the hour after the release (Figures 2.2 and 2.3).¹⁵

Yields continued to trend somewhat lower over the next hour, when they suddenly moved sharply lower just after 9:30am, despite the apparent absence of any news. In the six minutes between 9:33 am ET and 9:39 am ET, the 10-year yield decreased 16 basis points. Between 9:39 am ET and 9:45 am ET, the 10-year yield then abruptly reversed course and nearly retraced the latter move, again with no apparent trigger. These sharp moves between 9:33 and 9:45 am ET

¹⁴ The expected yield response to a surprise in retail sales (excluding automobiles) was calculated using yield changes corresponding to the retail sales excluding autos data releases over the preceding two years. The surprise on October 15 was 1.4 standard deviations from the mean, which would be associated with a 2 basis point decline.

¹⁵ Market depth is defined as the volume of orders available for execution in the CLOB, which is the set of standing orders at established prices available for execution at a given point in time.

represent the October 15 event window.¹⁶ Price volatility in the Treasury market declined noticeably thereafter, though the market was still more volatile than on an average day. Between 9:30 and 9:45 a.m., market depth in the 10-year security was about 20 percent of its year-to-date average for that 15-minute period. It recovered somewhat shortly thereafter, though remained lower than an average day.

For such significant price movements to rapidly occur without a clear catalyst in one of the world's most liquid markets in such a short period of time is highly unusual. Trading volumes in the Treasury market on the day posted record highs, and reached 6 to 10 times their average levels during the event window. Volumes in other electronic fixed income markets for which data is available, such as plain-vanilla interest rate swaps traded over Swap Execution Facilities (SEFs), were also high, though not to the same extent as in the Treasury market.

Despite the significant changes in many measures of liquidity, trading took place in a continuous fashion. No trades executed on the interdealer cash and futures platforms analyzed were broken or adjusted, nor was price “gapping”—or significant jumps from one price point to another with no transactions in between—a feature of trading on October 15. The magnitude of trading volumes and continuity of pricing showed that the ability to transact remained in place even at the most volatile times of the day, although individual trade sizes tended to be smaller than average.

While trading activity continued during this period, numerous market participants reported significant liquidity concerns. Some participants temporarily disengaged their automated price quoting systems and instead relied on manual or voice trading to reduce their risk. In the Treasury market, the market impact of transacting in large but not unusual size (for example, a quantity of \$100 million at the 10-year maturity point) would have required a trader

¹⁶ Specifically, during the event window, the 10-year Treasury yield fell from 2.02 percent at 9:33:19 ET to 1.86 percent at 9:39:39, before retracing to 1.99 percent at 9:44:35. Given the available data, no clear link has been identified between the event window and the open of the U.S. equity market at 9:30 ET.

to execute standing orders at price points far from the best bid or offer in the CLOB (Figure 2.4).

By the end of the U.S. trading session on October 15, the yield on the 10-year Treasury note was 2.14 percent, only six basis points below the closing level on the previous day, despite trading in an intraday range of 37 basis points. Intraday moves of this size are highly unusual; since 1998, larger intraday trading ranges have only been observed on three occasions.¹⁷ Moreover, in contrast to October 15, each of these other outsized intraday moves followed significant new fundamental information being received by markets. Further, two of the three instances resulted in a notably larger *net* change on the day as the market incorporated the new information. (Figures 2.5 and 2.6)

While the most pronounced moves on October 15 occurred in the Treasury market, other markets, especially those that are closely tied to U.S. interest rates, also experienced volatility. Intraday movements in interest rate swaps mirrored those in the Treasury market, and implied volatility on options on interest rate swaps rose markedly at all tenors. Implied volatility on options at some maturities rose by the largest amount in a single day since the financial crisis. Other asset classes, including foreign exchange, equities, and commodities also experienced some volatility on October 15, although moves in those markets were comparatively more modest (Figure 2.7).

The Market Environment

Several factors are important to understanding the market environment in the weeks and days preceding October 15, most notably increasing risks to the global economic outlook and the

¹⁷ The announcement of an increase in the large-scale agency asset purchase program and the introduction of Treasury security purchases on March 18, 2009, resulted in a 55 basis point intraday trading range and a net change of 47.5 basis points. The announcement of a coordinated cut in interest rates across major global central banks on October 8, 2008, resulted in a 43 basis point intraday trading range and a net change of 13.5 basis points. The introduction of calendar-based guidance into the FOMC statement and the downgrade of the United States' credit rating on August 9, 2011, resulted in a 40 basis point intraday trading range and a net change of 7 basis points.

unwind of substantial positions designed to profit from a rise in U.S. interest rates. A number of factors reportedly weighed on the global growth outlook. In the first two weeks of October, growth and deflation risks in the Eurozone, accompanied by uncertainty around the European Central Bank's response, generated considerable uncertainty on the part of investors. Many market participants reportedly viewed the tone of the annual IMF/World Bank meetings the weekend prior to October 15 as having exacerbated these sentiments. In addition, the minutes from the September meeting of the Federal Open Market Committee were widely interpreted by market participants as suggesting a somewhat weaker outlook for the U.S. economy than previously expected. Several investors also reported increasing concerns over the risks associated with a widespread Ebola outbreak. In response to these risks to the outlook, many investors turned to safe haven assets, driving up prices and lowering yields on U.S. Treasury securities and related instruments.

The moves in early October proved costly for investors who remained positioned for a rise in U.S. interest rates, rather than a fall. Based on data from the futures market, "short" positions on interest rates had become particularly popular among investors employing leverage, and were largely predicated upon an improvement in U.S. economic growth that would lead to a rise in short-term interest rates. Levered short positions in shorter-term interest rate futures contracts, such as Eurodollar futures, had reached a record level by the end of September. But as interest rates began to move lower in September and early October, leveraged funds unwound these short positions by offsetting their short exposure (Figure 2.8). Much of this unwind took place in the two weeks ahead of October 15, but the change was also significant on October 15 itself. These position changes were most notable in shorter-term rate instruments, but given cross-market linkages, likely had the effect of putting further downward pressure on yields across the Treasury curve.

In addition, market participants reported that some large asset managers had maintained positions structured to profit from a continuation of the low-volatility environment that characterized much of 2014, though data to validate such claims are limited. Some market participants have speculated that a change in the distribution of certain options-specific risk factors among certain firms could have been a contributing factor. In particular, anecdotal commentary suggested that some dealers had absorbed a portion of the sizable "short volatility"

position believed to have been previously maintained by large asset managers. As volatility spiked on October 15, those positions would have prompted some dealers to dynamically hedge this exposure, exacerbating the downward move in yields.

As a result of both the changing views and losses on interest rate positions (including exposure in related derivatives such as options), investors may have been particularly sensitive to new information that might confirm perceptions that the global growth outlook had dimmed. These factors may explain the abnormally large reaction to the modestly worse-than-expected retail sales data the morning of October 15. However, the timing of the window and the distinctive pattern of rapid price movements seem unlikely to have been driven by changes in growth expectations or even the effects of positioning unwinds. To better understand the nature and timing of the unusual price movements in the event window, Section 3 of this report examines several possible channels through which price formation could have been affected.

Section 3: Key Findings on October 15 and the Event Window

To shed further light on the developments of October 15 and in particular on the events leading up to and including the event window, staff examined participant-level transaction and order-book data from the primary locations for price discovery in the cash and futures markets. While the analysis revealed no single cause for the near round-trip in prices during the event window, data did highlight a number of important developments in the market before and during the event window, including a significant increase in volume, sizeable changes in market participation, a decline in market depth, shifts in the net initiated order flow, and certain notable trading behaviors, which together provide insight into the nature of the event. The analysis also revealed that changes to the Treasury market structure over recent years have been significant; these changes are likely important context for understanding the abnormally sharp period of volatility and for assessing the risk of reoccurrence of such an event.

Specifically, this section reviews analysis related to:

- trading activity and positioning,
- patterns of aggressive and passive trading activity,
- order book participation and liquidity provision,
- large transactions and orders, and
- notable trading activity.

Because analysis is ongoing and as noted earlier the data are an incomplete snapshot of the U.S. interest rate complex, the findings discussed in this report are necessarily preliminary and not comprehensive. Nonetheless, the analysis presented provides information that is useful in understanding the market conditions and the movements in prices on October 15, and it will serve as a foundation for future work in the area of Treasury market structure and functioning.

Trading Activity and Positioning

Analysis of trading activity and position changes was conducted in order to determine to what extent trading activity, large transactions, or changes in positions help explain the price dynamics during the event window. In total, the analysis found that on the day as a whole, the

two most active groups of participants were PTFs and bank-dealers, at levels consistent with their participation on the control days. Price movements in the event window coincided with a sharp increase in the total volume and share of trading generated by PTFs, with a decline in the share of trading generated by bank-dealers, but analysis thus far does not provide evidence that the abnormal price movements during the event window were caused by significant position changes.

On October 15, the data show that PTFs and bank-dealers, in that order, accounted for the largest shares of trading volume in both the cash and futures markets. In particular, PTFs accounted for more than 50 percent of the total trading volume across various maturities in both cash and futures markets, while bank-dealers accounted for roughly 30 to 40 percent of volume in the cash market, but under 20 percent in the futures market, perhaps owing to the greater variety of futures market participants trading directly or through a Futures Clearing Member (“FCM”) (Tables 3.1 and 3.2). The share of trading activity attributable to the various types of market participants on October 15 does not stand out as unusual relative to recent history. In particular, the PTF shares of trading volume in both the cash and futures markets on October 15 were similar to those on the control days (Tables 3.3 and 3.4). In terms of message traffic, defined as new orders, cancellations and modifications to existing orders, our analysis shows that PTFs represented around 80 percent of traffic in both futures and cash on October 15 (Tables 3.5 and 3.6). This was only slightly higher than for the control days, suggesting that their quoting behavior did not materially change.

During the event window, the data show that the relative share of PTF trading activity increased as prices and volumes rose sharply (9:33 to 9:39 ET), comprising about 73.5 percent and 68.4 percent of trading volume in 10-year note cash and futures markets, respectively, while the relative share of bank-dealer trading activity declined to 21.4 percent and 14.1 percent. Though the share of trading shifted toward PTFs, both PTFs and bank-dealers experienced an increase in their absolute level of trading volumes during this time, given the sharp increase in overall volumes. As the price quickly retraced its previous gains (9:39 to 9:45 am ET), the data show that the share of PTF trading activity declined somewhat from its elevated levels to 62.3 and 56.6 percent at the same time as the share of bank-dealer activity rose substantially to 33.6 and 24.5 percent in cash and futures, respectively (Figures 3.1 and 3.2).

Data from October 15 and control days show that the trading volume of PTFs and bank-dealers in the cash and futures markets is highly concentrated in the most active firms. Tables 3.7 and 3.8 show some measures of the concentration of activity among bank-dealers and PTFs in the cash and the futures markets on October 15 and on the control days, based on shares of trading volume. Generally speaking, the data show that there were only small differences in concentration levels between October 15 and the control days. In both the cash and futures markets, the concentration of PTFs was always much higher than that of bank-dealers.

In the cash market, for instance, the 10 most active PTFs (out of a total of 37) conducted 94 percent of the trading activity of all PTFs on October 15, while the 10 most active bank-dealers (out of a total of 44) accounted for 79 percent of the trading activity of all bank-dealers. A commonly used concentration metric, the Herfindahl-Hirschman Index (HHI) was about 0.23 for the top 10 PTFs, reflecting moderate concentration, while that of the top ten bank-dealers was 0.11, reflecting little concentration.¹⁸ The concentration findings were generally similar for the futures market, with readings a bit lower for PTFs, which are more numerous in futures than in cash, and a bit higher for bank-dealers, which are less numerous.

Despite the surge in trading volume during the event window, available data from the cash market do not show a significant change in net position by any specific participant type at that time (Figure 3.3). In the futures market, several participant types experienced small to modest changes in their aggregate net position during the event window. For example, hedge funds accumulated short and long positions, respectively, in the first half of the event window, which then unwound to varying degrees in the second half of the window (Figure 3.4).

¹⁸ The HHI is a commonly accepted measure of market concentration calculated by squaring the market share of each firm and then summing the resulting numbers. It takes values between $1/N$ and 1, where N is the number of firms, with values of the index closer to 1 indicating a higher degree of concentration. The Department of Justice classifies markets as unconcentrated, moderately concentrated, and highly concentrated according to their HHI. See: <http://www.justice.gov/atr/public/guidelines/hmg-2010.html#5c> for further details.

By contrast, in the period preceding the event window, various types of futures market participants, as a group, appeared to accumulate more significant positions following the data release at 8:30 am ET, including asset managers (who on net purchased futures and accumulated net long positions) and, to a lesser degree, bank-dealers and hedge funds (who on net sold futures and accumulated net short positions for periods of time). These results are consistent with the notion that a significant net change in positions by some market participants is likely important in understanding the large reaction to the retail sales data and the subsequent sharp increase in prices and volatility, but it does not appear to explain the round-trip in prices during the event window itself. Given these observations, questions about the specific factors triggering the move and later reversal remain open.

Patterns of Aggressive and Passive Trading Activity

During periods of significant directional market moves, an imbalance between the volume of buyer-initiated versus seller-initiated trades is commonly observed, with more buyer (seller) initiated trades during periods of steep price increases (decreases). A similar imbalance in this so called “net aggressive” trade flow was observed on October 15 during the event window.¹⁹ The analysis suggests that PTFs and bank dealers were the main contributors to the pattern of net aggressive flows, consistent with their large share of overall trading volume, with PTFs accounting for much of the imbalance in aggressive flows during the event window across futures and cash markets. At the same time, there is strong evidence from a study of net passive flows to suggest that PTFs, as a group, also remained engaged as liquidity providers throughout the event window, thus pointing towards more than one type of PTF strategies at work.

The net aggressive trade flow on October 15 in both the cash and futures markets was buyer-initiated during the first part of the event window when prices were rising and seller-

¹⁹ Every trade by definition comprises an “aggressive” and a “passive” side with the “passive” defined to be the standing order to buy or sell an instrument in the order book, while the “aggressive” order is that which is executed when matched against a standing “passive” order. The term “aggressive” therefore should not be seen as having a negative connotation in this context.

initiated during the second part as prices were falling, as seen in Figures 3.5 and 3.6. When decomposed by participant type, data show that both bank-dealers and PTFs were the main net aggressive buyers of Treasury futures as prices rose, and net aggressive sellers as prices fell. In the cash market, PTFs showed similar behavior. Bank-dealer flows, by contrast, appeared to be neutral in the cash market during the first part of the event, shifting to primarily seller initiated during the second part (as price declined). When considered across the cash and futures markets together, PTFs account for much of the net aggressive flows during the event window, consistent with their elevated share of overall trading volume.

A similar breakdown of the net *passive* trade flow by participant type in Figures 3.7 and 3.8, shows that PTFs were large net passive sellers during the first part of the event window and net passive buyers during the second part of the event in both cash and futures, consistent with market making activity and their large contribution to the depth at the top of the order book throughout the event window. Notably the PTF pattern of net passive flows closely mirrors the (inverted) pattern of PTF aggressive flows, such that, as a group, their net position remained largely unchanged throughout the event window. In contrast, net passive bank-dealer flows were not indicative of significant market making activity during the event window.

One possible explanation for the symmetry of the observed net aggressive buying and net passive selling flows by PTFs could be that this is evidence of hedging activity associated with the market making activities of these firms. For example, in a rising price environment, a market participant employing a market-making strategy would tend to see their passive offers to sell securities executed more often, and therefore over time accumulate a large negative position. In order to limit the market exposure associated with a sizeable short position, such a participant might choose to partially offset the passive sales by aggressively buying securities. In that case, the aggressive buy orders would only serve to decrease the exposure the firm accumulated in the process of market making activity and not be reflective of a directional market view.

However, an *algorithm-level* analysis from the event window on October 15 suggests that the aggressive buying during the first part of the event window was unlikely to be hedging flows arising from such market making activities. Indeed, this analysis indicates that aggressive buyer-initiated PTF trade flows during the first part of the event window mainly stemmed from trades

that served to increase, rather than decrease, the exposures associated with pre-existing positions at the time of each trade (Figures 3.9 and 3.10). In total, the analysis suggests that multiple types of trading strategies were deployed by PTFs during the event window. Some PTF algorithms appear to explain the considerable amount of net passive market making activity that was witnessed across cash and futures over the event window and likely was an important contributing factor to the absence of price gapping despite the unprecedented large price swings. Another, and equally significant, group of PTF strategies appears to have aggressively traded in the direction of price moves during the event window, accounting for the bulk of the overall aggressive trading imbalance observed.

As for bank-dealers, in the futures market the pattern of net aggressive trading during the first half of the event window was dominated by flows that increased exposure, similar to what was observed for PTFs (Figure 3.12). In the cash market however, where bank-dealer flows are likely to be motivated in significant part by the need to hedge client activity conducted in the dealer-to-customer market, the net bank-dealer flow was largely neutral during the initial part of the event, but switched to exposure reducing aggressive selling as prices subsequently declined (Figure 3.11).²⁰

Order Book Participation and Liquidity Provision

Analysis of order book participation and bid-ask spreads, important measures of the liquidity available in the market, was conducted in order to determine whether changes in the provision of liquidity were associated with the price dynamics during the event window. The data show that the two largest groups providing liquidity, PTFs and bank-dealers, both took actions to reduce their risk exposure to volatility during the event window, even as they

²⁰ While PTFs in general carry little inventory overnight, bank dealers do routinely end trading sessions with sizable long or short positions both in the cash and futures markets. In addition, bank-dealers historically have also warehoused significant positions accumulated from client trades in the cash market. It is therefore much more difficult in the cash market to identify exposure reducing vs exposure increasing trades for bank-dealers based on the data available to staff (inter-dealer cash platform and futures data only).

continued to trade. In general, the analysis shows that the spike in trading volume and volatility coincided with a sizeable reduction in the depth of orders provided by PTFs and with the posting of much wider bid-ask spreads by bank-dealers. In addition, for brief periods, bank-dealers were absent from the offer side of the cash market.

Market depth, which represents the amount of standing orders at the various prices available on the bid and ask sides of the order book, initially followed a typical pattern on the morning of October 15, but then deteriorated throughout the day. Figures 3.13 and 3.14 show depth for the cash and futures markets, respectively, at the first 10 price levels of the order book from 8:00 to 16:00 ET.²¹ In both markets, there was a sharp drop in market depth just ahead of the 8:30 ET retail sales data release that morning, which is a normal pattern ahead of a scheduled macroeconomic data release. Market participants reduce the level of potential risk exposure ahead of such known events by paring back the volume of standing orders they place on trading venues, reducing the risk that they end up transacting at an undesirable price.

Market depth recovered immediately after the 8:30 ET data release, but then diminished quite dramatically over the next hour in the run-up to the event window as Treasury yields gradually declined, a pattern consistent with the typical inverse relationship between volatility and market depth. During this period, there was evidence of some sizeable buy orders and position changes that coincided with notable reductions in the depth of the order book, although they did not result in price gapping. For example, near the beginning of the event window, two buy market orders were executed in the 10-year futures market—one for 3,000 contracts at 9:33:45 and one for 2,100 contracts at 9:34:07—both of which coincided with reductions in market depth.²² Around these and a number of other similar transactions, the liquidity consumed when the orders were executed was not fully replenished with new order submissions, leaving the market with reduced depth of book—particularly on the offer side. Thus the data show that

²¹ In futures markets the top 10 levels represent the entire book visible to subscribers, whereas in cash the entire order book is visible in the most detailed commercial data feeds.

²² The notional contract size for the 10-Year Treasury Note future is \$100,000.

the most extreme period of volatility, the event window, began at a time when market depth was thus already low, likely increasing the transaction costs and price impact of larger trades. Market depth then dropped even further during the event window as volatility rose. Given the rapid movement in prices over this short time interval, and thus the speed with which the best bid and offer levels changed, there was obviously a reduced amount of time for the depth of book to be replenished at the prevailing price.

Decomposing the decline in market depth by participant type shows that PTFs and bank-dealers adjusted their liquidity provision on October 15 in very different ways. Data from the control days show that, in “normal” market conditions, PTFs provide the bulk of the available depth at or near the highest bid price or the lowest ask price (the “top of the book”) in both the cash and futures markets. On October 15, the drop in available depth that followed the data release at 8:30 ET was due primarily to a large reduction by PTFs of the limit orders they left standing in the cash and futures markets (Figures 3.15 and 3.16). The decline in limit orders made available by bank-dealers was less substantial in absolute terms because they routinely leave far fewer limit orders standing near the top of the book.

In the initial part of the event window, however, there were periods of time when bank-dealers had no, or very few, orders in the offer side of the cash market. When prices rose during the initial part of the event window, the PTF share of the order book increased to an average of 80 percent of depth at the top 3 levels of the book in cash and 64 percent in futures, with dealers accounting for less than 15 percent. As prices declined in the second part, the PTF share of order book depth declined to an average of around 65 percent in cash and 52 percent in futures, while the bank dealer share rose to around 30 percent of depth in both cash and futures (Figures 3.17 through 3.22). Thus the pattern of order book participation largely mirrored the pattern of trading volume shares observed above.

Although they significantly reduced their depth of orders, the data also show that PTFs as a group continued to provide the majority of order book depth and a tight spread between bid and ask prices throughout the day, even during the event window (Figures 3.23 and 3.24).²³ In contrast, during the event window, the bank-dealers that remained present in the market significantly widened their bid-ask spreads such that they only provided limit orders at a substantial distance from the top of the book.²⁴

In very broad terms, therefore, PTFs, as a group, reacted to the event of October 15 primarily by reducing limit order quantities, while the bank-dealers reacted by widening bid-ask spreads and, for brief periods of time, removing their offers to sell securities. Both actions served as risk management strategies by reducing the number and size of orders that could be executed, and also caused a sharp drop in the supply of liquidity to the market.

An analysis of the relative supply of liquidity in the bid and offer sides of the order books by participant type shows certain imbalances in the provision of liquidity during the event window (Figures 3.21 and 3.22). PTFs, as a group, contributed to the order book in a relatively balanced fashion throughout the window, often providing standing bids and offers of approximately similar sizes, though at low absolute levels. In contrast, the balance of bids and offers supplied by bank-dealers was considerably more variable during the event window. During the first part of the event window, as dealers intermittently removed their orders to sell securities in the cash market, the balance of their remaining orders became skewed toward purchase orders. Despite limited and at times imbalanced order book participation, bank-dealers continued to trade actively during the event window, and indeed the absolute volume of their trading increased.

²³ For instance, in the futures market, the average bid-ask spread on October 15 was equal to 1.2 ticks, where 1 tick is equal to 1/32 of a percentage point in price terms. This compares to an average of about 1.05 tick on our low-volatility control days.

²⁴ During the brief moments in the event window when bank-dealers, as a group, only posted purchase orders in the cash market, no bank-dealer bid-ask spreads genuinely existed.

Around 9:39 ET, the sudden visibility of certain sell limit orders in the futures market seemed to have coincided with the reversal in prices. Recall that only 10 levels of order prices above and below the best bid and ask price are visible to futures market participants. Around 9:39 ET, with prices still moving higher, a number of previously posted large sell orders suddenly became visible in the order book above the current 30-year futures price (as well as in smaller size in 10-year futures). The sudden visibility of these sell orders significantly shifted the visible order imbalance in that contract, and it coincided with the beginning of the reversal of its price (the top of the price spike). Most of these limit orders were not executed, as the price did not rise to their levels.

Large Transactions and Orders

The data for October 15 do not show an exceptionally large trade or a series of related large trades that appear to be the direct cause of the sharp price movements observed during the event window. Such trades, had they existed, might have been a sign of a “fat-finger” operational or systems error, or of severe stress by a particular market participant. Buy orders of reasonably large sizes were seen both preceding and at the beginning of the event window in the futures market, but they did not directly coincide with substantial price movements (Figure 3.25). Moreover, trades of the sizes seen in this event occur regularly, for instance during the control days of the data sample, and they generally do not generate very large price movements.

Historically, sizable market and stop-loss orders have on occasion precipitated or exacerbated large moves in financial asset prices, particularly when they lead to trade executions far from the price that prevailed when they were initiated. Market orders are often used by market participants in CLOBs when they wish to conduct a transaction for a financial instrument irrespective of the price, perhaps for hedging purposes or to ensure the timely change in a position. There were only a limited number of market orders seen in the data for October 15, including two (described in the preceding section) that occur at the start of the event window; none of these appear to have resulted in sizeable changes in prices.

Stop-loss orders are conditional resting orders that execute in the direction of a price move after a trigger price is hit. These orders are often used by market participants to protect

against incurring substantial losses when the price of an asset is moving substantially. The stop-loss order activity that existed on October 15 across the array of interest rate futures contracts was small on October 15, and very limited “buy volume” was triggered during the upward price movement of the event window as a result of these orders. Additionally, the trades that did result from these resting orders were executed very close to the trigger price, suggesting they did not prompt sizeable changes in prices. There is no stop-loss order type on cash platforms.²⁵

While the large orders did not result in significant price movement leading up to or during the event window, they did coincide with notable reductions in market depth preceding and at the start of the event window. Indeed, it seems that large orders were thus more likely to have contributed to the erosion in liquidity that occurred in the hour preceding the event window, rather than serving as a driving factor of prices during the event window itself.²⁶

Notable Trading Activity

Analysis of transaction and order book data during the event window revealed two notable patterns in activity on October 15, high levels of cancellations and self-trading, but whether this activity contributed to the rapid price movements is unknown.

First, the number of new order submission and cancellation messages sent to the futures exchange and the cash trading platforms on October 15 was very high, as would be expected on a highly volatile day. In the futures market, this was accompanied by temporary sharp increases in latency, the time required by the matching engine to process incoming orders. Figure 3.26 shows that message rates for new orders and cancellations across Treasury futures contracts were elevated during the event window, though they varied considerably over the trading day. The

²⁵ In both cash and futures markets, stop-loss orders could also be directly generated by traders or their computers in real time, and not entered ahead of time on the trading platforms. These orders would not be captured as “market orders” in the available data.

²⁶ Additionally, there was a somewhat elevated level of trading volume in exchange-for risk and block trades in the futures market. Such transactions take place outside the CLOB. Data limitations prevent a thorough analysis of the potential impact of such trades, but further study of the dynamic between trades done off of electronic venues and market conditions may be warranted.

largest of these spikes in message rates coincided with the cancellations of a very large number of limit orders outside the visible order book, and thus far from the current market price (Figure 3.27); these cancellations were made by a relatively small number of firms with minimal trading volume on the day.

Given the finite capacity of any matching engine to simultaneously process messages and execute matches between buyers and sellers, extremely high message rates appeared to cause trading platform latency to temporarily jump higher (Figure 3.28).²⁷ Figure 3.29 shows the message rate and latency build-up within a single second around 9:34 ET at millisecond resolution, illustrating how a peak message rate of around 40 messages per millisecond results in a gradual slowing down of the response time of the matching engine. Once the messaging rate fell, trading platform latency quickly returned to previous low levels. While the message cancellations observed very near the beginning of the event window were not a direct cause of price movements at the time given their distance from the market price, the associated latency would have affected the trading speeds of other market participants by increasing the time lag between initial order entry and possible execution on the platform. As some market participants monitor latency and include it as a variable in their trading strategies, sudden changes in latency would cause them to adjust their behavior.

The cancellation activity witnessed in the invisible futures order book also resulted in a highly volatile total order book depth (including visible and invisible orders) in the futures market (Figure 3.30). In the futures market, the portion of the order book that is not visible to market participants (that portion that rests at levels outside the top 10 best bid and offer price levels) can represent anywhere from 50 to 90 percent of total market depth—witnessed both on October 15 and the control days.

²⁷ Such latency is defined as the time between when an order is generated by a firm and when it gets added to the order book at the exchange.

A second notable aspect of trading on October 15 was the heightened level of self-trading during portions of the event window. Self-trading, for the purpose of this report, is defined as a transaction in which the same entity takes both sides of the trade so that no change in beneficial ownership results. Self-trades appeared in both cash and futures market data at varying levels across firms and time periods.²⁸ In the cash market for 10-year Treasury securities, for example, self-trading represents 5.6 percent of the total activity on control days, and 4.2 percent on October 15 (Table 3.9).

The bulk of self-trading in cash and futures markets was observed among PTFs, perhaps due to the fact that such firms can run multiple separate trading algorithms simultaneously. For instance, one of these algorithms could specialize in placing buy or sell limit orders at the top of the order book while another could specialize in initiating trades given specific conditions in that market, potentially leading one algorithm to end up being matched with another algorithm from the same firm.²⁹ In addition to PTFs, the cash data also showed a very small amount of self-trading by bank-dealers and hedge funds, some of which are also known to trade algorithmically. In the futures market, the share of self-trading was generally similar to the cash market, and the

²⁸ At times, self-trading may reflect unlawful conduct. For example, unlawful self-trades may constitute “wash sales.” In the futures markets, “wash sales” involve a purchase and sale of the same delivery month of the same futures contract at the same or similar price, made without an intent to take a genuine, bona fide position in the market, and instead, are intended to negate risk or price competition. In the securities markets, for example, a “wash trade” is a transaction that does not result in a change of beneficial ownership when there is a fraudulent or manipulative purpose behind the trade. This report is not making any findings on the legality of any self-trading that occurred on the days covered in this analysis.

²⁹ In general both cash and futures platforms provide a “self-match prevention” flag which allows participants to avoid self-trading by having the matching engine reject such matches. Some exchanges require the use of the self-match prevention for certain participant types, whereas for others use is voluntary. Where voluntary, not all market participants choose to use that feature. In addition, many firms have internal self-match prevention tools which may provide more customized solutions than those at the exchange. See <http://www.cmegroup.com/globex/trading-cme-group-products/self-match-faq.html> for related information from the CME Group. See also <http://www.gpo.gov/fdsys/pkg/FR-2014-05-07/pdf/2014-10384.pdf> for rules adopted by FINRA to address patterns of unintentional self-trading by its members in securities, including the cash Treasury market. The FINRA rule defines “self-trades” as securities transactions that result from the unintentional interaction of orders originating from the same firm that involve no change in the beneficial ownership of the security. Among other things, the rule requires FINRA members to have policies and procedures in place that are reasonably designed to review their trading activity for, and prevent, a pattern or practice of self-trades resulting from orders originating from a single algorithm or trading desk, or from related algorithms or trading desks..

activity was also almost exclusively limited to PTFs. In contrast to the cash market, however, there was a higher incidence of self-trading on October 15 (4.2 percent) than on the control days (2.7 percent) for the 10-year contract (Table 3.10).

During the event window, the data showed that the share of overall transactions resulting from self-trading was substantially higher than average. At the 10-year maturity, it reached 14.9 percent and 11.5 percent for cash and futures, respectively, during the move up in prices in the event window (Figure 3.31). During the retracement, when the price moved back down rapidly, the share of self-trading declined to 1.2 percent and 4.8 percent in cash and futures, respectively. Moreover, the concentration of self-trading volume among PTFs was very high in both markets during the event window. Another aspect of self-trading flows during the event window was its directional nature (Figures 3.32 and 3.33). For example, between 9:33 and 9:39 ET, the cumulative net aggressive buyer- minus seller-initiated self-trade volume increased by around \$160 million in the cash 10-year note, accounting for close to one-fifth of the total imbalance between buyer and seller initiated trades observed over that time interval.³⁰

Summary of Analytical Findings

Analysis of participant-level data in the cash and futures markets did not reveal a clear, single cause of the price movement during the event window on October 15. However, the data did highlight a number of important characteristics of the event. They revealed that PTFs remained the dominant participant type during the event window: they produced high trading volumes during the event window, and continued to provide liquidity to the cash and futures order books, though at much reduced levels. Bank-dealers also increased their trading volumes, but to a much lesser extent, and provided less liquidity in the order books by widening their spreads and withdrawing for brief periods from the offer side of the book. The dynamics that drove continued trading at such volume during that short period of time remain an open question.

³⁰ Qualitatively similar patterns, albeit larger in magnitude, were observed in the 5-year note in the cash market, where self-trading accounted for about one-third of net aggressive trade volume between 9:33-9:39 ET.

During the event window, an imbalance between the volume of buyer-initiated versus seller-initiated trades was observed, with more buyer-initiated trades as prices rose in the first part of the event window, and more seller-initiated trades as prices fell in the second part of the event window. Such imbalances are common during periods of significant directional market moves. Both bank-dealers and PTFs initiate these liquidity removing trades, though PTFs account for the largest share. At the same time, there is strong evidence to suggest that PTFs, as a group, also remained engaged as liquidity providers throughout the event window, thus pointing towards more than one type of PTF strategies at work.

Data from the markets analyzed in this study did not reveal any market orders, stop-loss orders, or other types of transactions of highly unusual size that appear to have driven the price movements in the event window. A few buy orders of large, but not unusual size, ahead of the event window were associated with a reduction in market depth in the cash and futures markets. Market depth reached particularly low levels around the start of the event window, and, in the absence of new orders to replenish the order book, did not fully recover for a period of time. Importantly, analysis shows that in the Treasury cash and futures markets, the nature of trading and types of market participants have changed significantly over the last decade.

Section 4: Observations about Treasury Market Structure

The preceding analysis does not reveal a single cause for the volatility seen on October 15—particularly so for the event window. However, as explored further in this section, the data do suggest that the structure of the U.S. Treasury market has evolved notably in recent years. In particular, the increased use of electronic trading and the shifting roles of market intermediaries, especially in cash Treasuries, as well as changes in end investors, may have resulted in changes to how liquidity is provided and demanded, and to the characteristics of that liquidity. An improved understanding of these issues sheds additional light on how the events of October 15 may have transpired, and raises questions about whether events such as October 15 could occur more frequently going forward.

Increase in electronic trading

Electronic trading has become an increasingly important feature of the modern Treasury market. While it has been well established in the futures market since the late 1990s, it had its start in the interdealer cash market in the early 2000s, when the interdealer brokers first launched their electronic platforms for Treasuries, and opened access to non-dealers. These electronic trading platforms enabled automated trading – a subset of electronic trading that relies on computer algorithms for trading decisions, execution, and booking. As a strategy, a variety of firms employ automated trading of some form, from small proprietary trading operations to large hedge funds and traditional broker-dealers.

The vast majority of trading in the interdealer cash Treasury market takes place in the most recently issued securities (also known as “on-the-run” or “benchmark” securities) given – and contributing to – their superior liquidity. Trading in the on-the-run securities tends to concentrate on the electronic platforms, with interdealer trading in seasoned securities (also known as “off-the-run”) taking place primarily through traditional voice-assisted brokers.

The growth in electronic trading has contributed to a marked shift in the composition of participants in the interdealer cash market over time.³¹ Until 1992, for example, the interdealer brokers only allowed primary dealers, as designated by the Federal Reserve Bank of New York, to access their trading platforms. In 1992, the interdealer brokers expanded access to all entities that were netting members of the Government Securities Clearing Corporation (now the Fixed Income Clearing Corporation, or FICC). Over time, other entities gained access to the platforms through their prime brokers, who themselves had access, and the platforms in recent years granted direct access to an even wider range of participants, including those outside the FICC netting membership. In particular, PTFs gained access to the platforms in the mid-2000s. Because of the broader access to futures markets, such firms have been a core presence in those markets for a longer period.

PTFs now account for more than half of the trading activity in the futures and electronically brokered interdealer cash markets, as shown earlier for October 15 and control days. Moreover, activity among PTFs tends to concentrate among a small number of firms, more so than activity among dealers (Tables 3.7 and 3.8). While these data suggest that PTFs' share of activity on October 15 as a whole was not significantly outsized, they point to the key role a small number of PTFs play on a routine basis in liquidity provision and price discovery.

The growth in automated trading has also raised questions about evolving risks. Automated trading can occur at speeds that exceed the capacity of manual detection and intervention, posing a challenge to traditional risk management protocols, and forcing market participants, trading platforms, and clearing firms to develop internal risk controls and processes

³¹ In contrast to the interdealer market, where brokers facilitate anonymous trades between counterparties, dealer-to-customer trades occur directly between broker-dealers and end investors. A good deal of the dealer-to-customer activity still takes place over the phone. However, electronic trading has also permeated this market, albeit to a lesser extent and in a different manner from the interdealer market. In particular, electronic trading in the dealer-to-customer market takes place through execution platforms in which market participants can request quotes from multiple dealers, or through single dealer platforms in which dealers stream quotes to their customers. The analysis in this report does not speak to this segment of the market.

to manage the potential for rapidly changing market and counterparty risk exposures.³² Risks associated with automated trading have been acknowledged by a range of market participants and regulators, and a summary of such risks can be found in Appendix C.³³

Changes in liquidity supply

The growth in electronic trading, competitive pressures, regulation, and other factors have led to changes in the suppliers of liquidity and the manner of liquidity provision in recent years, with implications for the characteristics and measurement of liquidity. Dealers have traditionally acted as short- to medium-term liquidity providers, often buying or selling from customers in large amounts, holding a portion of these positions across days, and maintaining a large balance sheet to support such positions. Dealers profit from liquidity provision via collecting the bid-ask spread, but also from coupon income and potential price appreciation on positions taken in their market-making capacity, and from insights gathered from their views of customer flows. Moreover, dealers may, in an effort to satisfy client expectations, be willing to provide liquidity to clients even when doing so may not be immediately profitable.

However, the entrance of a broader range of firms in the market and the expansion of electronic trading has increased competitive pressures. Market making revenues are now distributed across a broader set of entities and entity types, consistent with a competitive marketplace. Anecdotally, market participants have claimed that dealers are more circumscribed in the utilization of their balance sheet to intermediate markets in order to better manage their exposure and risk.

³² Given central clearing in futures, counterparty risk exposures there are managed by the clearing house.

³³ These risks are also discussed in the Treasury Market Practices Group white paper “Automated Trading in Treasury Markets,” <http://www.newyorkfed.org/tmpg/>. The white paper includes a set of recommendations for market participants, to supplement previously issued best practices, in response to these risks. The CFTC has also implemented numerous rules addressing risk management concerns in futures. Through its recent Concept Release on Automated Trading, CFTC is engaged in consultations with market participants on the need for additional risk control related regulations for automated trading in the futures markets.

<http://www.cftc.gov/ucm/groups/public/@newsroom/documents/file/federalregister090913.pdf>

Some market participants have argued that recent regulatory initiatives have increased trading and inventory costs and forced a reduction in risk-taking, prompting them to shift their allocation of capital away from market making for low margin transactions, and instead towards other business areas that may yield greater returns on equity. Indeed, some of this capital reallocation could have been expected from regulatory changes intended to increase the resiliency of financial institutions and of the financial system.³⁴

There is evidence that dealers have pared their risk-taking in recent years in reaction to the crisis, new competitive pressures, new regulations, and other factors. Financial assets of security brokers and dealers fell sharply during the crisis, for example, and have since stagnated (Figure 4.1). With respect to the Treasury market in particular, commentators sometimes point to the aggregate net positions of primary dealers as a gauge of dealer risk taking (Figure 4.2), but the offsetting nature of different dealers' positions in this measure limits its value for this purpose. Perhaps more informative is dealers' gross Treasury positions (Figure 4.3), which sum across short and long positions, and an estimate of dealers' market making positions (Figure 4.4). Both measures plunged during the crisis, but more than fully recovered in subsequent years. As noted by some market commentators, however, dealer positions relative to outstanding debt have fallen in recent years given the growth in debt outstanding.

In contrast to dealers, PTFs commonly act as short-term liquidity providers, buying and selling frequently in small amounts, but rarely taking significant, unhedged intraday positions and typically ending the day with little net directional exposure. Because they take on little net exposure, and, in cash Treasuries, rely on prime brokers for their financing and clearing needs, many PTFs can be more thinly capitalized than typical broker-dealers. Most PTFs do not trade on behalf of clients and instead restrict their trading activity to proprietary positions. As a result,

³⁴ Evidence to date is limited on whether regulatory changes have affected dealer market-making behavior. For example, an analysis of the sharp rise in yields in 2013 showed that dealers reduced their holdings of Treasury and other fixed income product positions at the time, but found no quantitative evidence that such behavior was directly related to diminished risk-taking capabilities. See "Dealer Balance Sheet Capacity and Market Liquidity during the 2013 Selloff in Fixed-Income Markets," by Tobias Adrian, Michael Fleming, Jonathan Goldberg, Morgan Lewis, Fabio Natalucci, and Jason Wu, Liberty Street Economics blog post, October 16, 2013.

these firms make trading decisions, including liquidity provision decisions, primarily on the basis of immediate profitability and the level of market risk, rather than as a service offered in the context of existing customer relationships that are intended to be profitable over time.

Analysis of order book data in the cash and futures markets shows distinctive patterns in how PTFs and bank-dealers adjust their provision of liquidity in volatile periods. As discussed earlier, bank-dealers tended to manage risk on October 15 by adjusting the price at which they were willing to transact – widening the spread between their bids and offers as price volatility increased, and withdrawing from the offer side of the market during the period of the sharpest price rise – rather than relying fully on adjustments to the quantity of orders made available (though this was an additional factor). In contrast, PTFs almost exclusively reduced their risk by trimming the quantity of standing orders to buy and sell, but generally maintained, as a group, a narrow spread between their bid and offer prices. This behavior may reflect the advantages of speed: PTFs can likely monitor and respond to price movements more quickly than many other market participants, adjusting their provision of liquidity very rapidly, and thus manage their price risk more dynamically.

While PTFs are able to provide very tight bid-ask spreads even in a volatile market, and help ensure that prices rapidly reflect new information, such firms typically do not wish to establish significant positions, and may not have the capital to compete for large buy and/or sell orders. Moreover, unlike dealers, PTFs do not have access to a customer business to assess current and latent demand for liquidity and therefore have to spend considerable effort on processing the information content of incoming order flow. To ensure that their quotes do not become stale and result in unprofitable trades, such firms quickly cancel or modify existing quotes if they sense the price is about to move in an unfavorable direction. Such behavior is a rational risk management device for PTFs operating in markets where bid and offer quotes are binding (as opposed to some markets where quotes are indicative or can otherwise be withdrawn).

Changes in liquidity demand

The demand for liquidity is also changing, in parallel with the changes in liquidity supply. The most notable factors may be the growth of Treasury debt outstanding, the changing shares of debt held by different investor groups, and the increased concentration of holdings among money managers.³⁵ These developments raise concerns that transaction flows, and the associated demand for liquidity, may become larger and more volatile in an environment where the business of liquidity provision and operating technology of markets have gone through fundamental changes.

The amount of Treasury debt outstanding grew sharply during and after the financial crisis as net debt issuance rose to finance the federal government's budget deficits. Marketable debt outstanding totaled \$12.6 trillion as of April 30, 2015, up from \$4.3 trillion on June 30, 2007, before the crisis.³⁶ All else equal, the growth in debt outstanding could be expected to increase liquidity demands as security ownership and flows increase correspondingly.

Aside from the growth in debt outstanding, there is the question of whether the allocation of that debt has shifted towards investors who are typically liquidity seekers in the secondary markets. Figure 4.5, for example, shows that the share of Treasury securities held by mutual funds (including closed-end funds and exchange-traded funds) has increased in recent years, from just under 4 percent in the years preceding the financial crisis to 6.7 percent at the end of March 2015.³⁷ Mutual funds provide daily liquidity to their investors – investing cash or meeting redemptions – and hence demand immediate liquidity from dealers. Figure 4.6 shows that the magnitude and volatility of these flows, as measured on a monthly basis, has increased markedly in recent years.

³⁵ For further discussion of the trends affecting market making, see CGFS Papers No 52, “Market-making and proprietary trading: industry trends, drivers and policy implications,” Report submitted by a Study Group established by the Committee on the Global Financial System, November 2014, <http://www.bis.org/publ/cgfs52.pdf>.

³⁶ These figures include holdings of the Federal Reserve, which totaled \$0.8 trillion on June 30, 2007 and \$2.5 trillion on April 30, 2015.

³⁷ These percentages include Federal Reserve ownership of Treasury securities in the denominator. If Federal Reserve ownership is not included, then the share increases from about 4.5 percent in the years preceding the crisis to 8.2 percent at the end of March 2015.

That said, ownership of Treasury securities has shifted in numerous ways. Ownership by foreign investors, for example, which is the residual investor group in Figure 4.5, increased from 37.8 percent at the end of 2003 to 47.3 percent at the end of March 2015. This category includes foreign central banks and sovereign wealth funds, which may have a reduced need for market-making services relative to other investors because their investment horizon may be longer. On balance, the *shift* in ownership among investor types does not clearly point to an increased or decreased the demand for market-making services, although the absolute *growth* in the level of the debt has likely increased the demand for such services.

Aside from shifts in ownership among investor groups, there is evidence that concentration within the money management industry has increased. Some market participants suggest that this concentration may lead to more concentrated demands for liquidity provision, presumably under the idea that assets within a given money management firm are more likely to be managed in a similar way than assets managed by several different firms. That is, portfolio allocation decisions, and hence liquidity demands, may be more dependent on the portfolio allocation decisions of a small number of large financial institutions.

Implications of structural changes for liquidity

The overall implications of these structural changes for Treasury market liquidity, and whether they suggest that events like October 15 are more likely, are unclear. By some metrics, market liquidity is as good or almost as good as it has ever been. Bid-ask spreads in the interdealer market remain close to the narrowest they have ever been, after having increased sharply during the 2007-09 financial crisis (Figure 4.7). The “noisiness” of Treasury yields, which measures the dispersion of market yields around a fitted yield curve, shows a similar pattern (Figure 4.8). Trading volume of primary dealers is somewhat lower than observed in the years before the crisis (Figure 4.9), but trading volume of benchmark securities in the interdealer market, which reflects activities among a broader set of firms, is near historically high levels for

the 5- and 10-year notes (Figure 4.10).³⁸ Trading volume in futures, in contrast, has not exhibited a strong upward or downward trend since the first half of 2007, before the financial crisis (Figure 4.11).

Some other liquidity measures exhibit some deterioration of liquidity. Order book depth of benchmark notes in the interdealer market reached post-crisis highs in early 2013, but declined during the 2013 selloff in the fixed income markets, and again in late 2014 (Figure 4.12). Price impact coefficients, which measure how much prices tend to change for buy or sell orders of a given size, spiked up on October 15 and remain somewhat higher than they were in early 2014 (Figure 4.13).

While some measures demonstrate a favorable liquidity environment, liquidity remains a concern among some market observers because of the structural market changes that have occurred. There are also concerns because of liquidity reductions during times of stress, such as on October 15 and during the selloff in fixed income markets in 2013, although the relationship between volatility and liquidity is obviously not just a recent phenomenon. In particular, while liquidity often is high, and, on average, may have benefited from the advent of electronic trading, the changing nature of liquidity provision may have increased the likelihood of periodic episodes of intraday volatility, such as that observed on October 15. That is, as the speed of market activity has increased, substantial variations in market liquidity may have become more frequent than in the past.

In addition, the high levels of liquidity observed in recent years have come in an environment of unusually low market volatility and high security supply, which tend to benefit liquidity.³⁹ Liquidity could naturally be expected to deteriorate somewhat if and when volatility

³⁸ Trading volume for the 2-year note remains far below its highs in 2007 and 2008, likely reflecting the low volatility and trading interest in the note during the prolonged period of overnight rates at the zero lower bound.

³⁹ In fact, when evaluating trading activity, some market participants prefer turnover measures, which take the quantity of outstanding debt into account, and which have shown a sharp decline as debt outstanding has grown. However, it is not obvious that one would expect trading volume to vary one-for-one with the level of outstanding debt and hence unclear whether this is a better measure of activity.

rises.⁴⁰ Some market participants have expressed concern that a shift in investors' views, in an environment where the volatility of investor flows have increased and where dealers have pared back their market making capacity, could pose a challenge to market liquidity.

The potentially higher risks of spikes in volatility and declines in liquidity raise questions about the appropriate response. This is complicated by the fact that rapid price changes and changes in the level of liquidity can also arise naturally in response to new developments and high uncertainty. To mitigate the likelihood and effects of sharp intraday rises in volatility or changes in liquidity, market participants and venues have adjusted trading strategies and risk management practices to better prepare for such episodes. The CME Group, for example, introduced a new rule regarding price fluctuation limits for certain interest rate futures and options contracts in December 2014 to “deter sharp price movements that may, for example, be driven by illiquid central limit order books prevailing from time to time in otherwise liquid markets.”⁴¹

Aside from the potentially higher risks of increases in volatility and declines in liquidity, the changing nature of liquidity provision means that the measurement of liquidity may need to change. Indeed, one measure of liquidity, trade size, has decreased markedly in recent years in both the interdealer and futures markets (Figures 4.14 and 4.15), but that decrease at least partially reflects the adoption of automated trading in electronic markets with pre-trade transparency. More traditional liquidity metrics continue to look favorable, as mentioned above, but may provide only a partial view into liquidity availability as a whole. The ability of liquidity providers to detect orders and react to new information is nearly instantaneous, and can lead to rapid shifts in the state of the limit order book. Average bid-ask spreads and market depth, though often indicative of general market conditions, may need to be complemented by other

⁴⁰ Volatility tends to be positively related to trading activity, but negatively related to more direct measures of market liquidity, such as bid-ask spreads and depth.

⁴¹ See <https://www.cmegroup.com/tools-information/lookups/advisories/ser/files/SER-7259.pdf>

measures in light of these changes to obtain a more meaningful picture of the state of market liquidity in the current market structure.

Section 5: Next Steps

The events and analysis of October 15 have highlighted the importance of the depth and liquidity of the U.S. Treasury market, and have led to important questions about the implications of structural and other changes currently underway in the market. The staff of the Treasury, Board, FRBNY, CFTC, and SEC plan to continue to analyze the events of October 15 and examine changes in the U.S. Treasury market structure, and have identified four areas for further work. These include:

- Further study of the evolution of the U.S. Treasury market and the implications for market structure and liquidity,
- Continued monitoring of trading and risk management practices across the U.S. Treasury market and a review of the current regulatory requirements applicable to the government securities market and its participants,
- An assessment of the data available to the public and to the official sector on U.S. Treasury cash securities markets, and
- Continued efforts to strengthen monitoring and surveillance and promote inter-agency coordination related to the trading across the U.S. Treasury market.

Understanding the implications of changes to U.S. Treasury market structure and liquidity

The U.S. Treasury market is the deepest and most liquid government securities market in the world. However, an event like October 15 highlights the need to better understand various factors that are impacting liquidity in the U.S. Treasury market, especially during stressed market conditions. These include changes in intermediation, automated trading, regulation, and buy- and sell-side participation that may have altered trading practices as well as the sources and characteristics of liquidity provision. Because of the U.S. Treasury market's unique role, changes in market structure and liquidity could also have implications for the cost of financing the government, how these instruments are used as risk-free benchmarks for pricing financial instruments, the costs borne by investors transacting in these markets, and the implementation of monetary policy. In order to better understand the key factors underlying the current market

structure and how they influence the liquidity of the U.S. Treasury market, the following next steps are recommended:

- Continue to study U.S. Treasury market structural changes and implications for market functioning and efficiency.
- Continue to support existing forums where market participants, the public, and regulatory agencies discuss issues related to investment trends, market structure, risk management and automated trading in financial markets, including the U.S. Treasury market
- Host a public-private sector conference, and encourage associated studies, addressing changes to the U.S. Treasury market and the effects on liquidity provision, risk management and market participation

U.S. Treasury market regulatory requirements and trading and risk management practices

The introduction and rapid growth of automation in the U.S. Treasury market over the past decade has brought benefits as well as challenges to trading practices and risk and internal control systems. Risk controls at firms and trading venues must be able to monitor order and trade activity at the increased speeds made possible by this automation. In recent years, many trading platforms and firms have improved their risk management practices to better align with the faster trading environment, often aided by best practices drafted by industry or public bodies. The trend toward increasingly automated and algorithmic trading on trading platforms is also being addressed by various regulatory efforts underway by the SEC, the CFTC and others. To further these steps, the public and private sectors must continue to work together to address the outstanding risks, including operational risks and risks that may harm liquidity provision or price discovery.

Market structure changes also suggest that a review of the regulatory requirements applicable to the government securities market would be worthwhile. The GSA, which provides for the registration of government securities brokers and dealers engaging in transactions in the cash markets for government securities, requires Treasury to adopt rules with respect to financial responsibility and related practices of government securities brokers and dealers. In order to prevent fraudulent and manipulative acts and practices and to promote just and equitable

principles of trade, the GSA also authorizes the appropriate regulatory agencies (the SEC and federal bank regulators) to issue regulations, in consultation with Treasury, with respect to transactions in government securities for the entities they regulate. The enforcement authority for these rules sits with the SEC, FINRA or the appropriate bank regulator. There are, however, several differences in the current regulatory requirements applicable to the government securities market as compared to other U.S. securities, commodities and derivatives markets that may be worthy of examination. The authors of this report:

- Support a review of the current regulatory requirements applicable to the government securities market and its participants.
- Suggest studying the implications of a registration requirement for firms conducting certain types of automated trading in the U.S. Treasury market and for government securities trading venues.
- Support industry and other efforts to develop, and regularly revisit, best practices for market conduct related to voice and automated trading in cash and futures markets.
- Continue to review policies and risk management practices at U.S. Treasury trading venues to assess risks posed to trading, risk transfer, and price discovery, as well as clearing and settlement risks associated with the increased speeds of automation.

Publicly available data around U.S. Treasury market activity and functioning

Public transparency surrounding trading activity in the U.S. Treasury market is critical to investor confidence and the liquidity of these markets. Data related to order and trade activity is currently published by various agencies and trading venues, informing the public, on an ongoing basis, about market prices, trading volumes, market participant inventories and trends in market risk and liquidity. However, differences in pre- and post-trade public reporting exist, especially between futures and Treasury cash securities, and the level of publicly available information is often not consistent across Treasury market venues or products. For example, in the futures markets, anonymous transaction information is visible to market participants and aggregated position information for large traders is publically available; futures venues and participants also provide regulatory information on participant-level transactions and positions. Given the fragmented nature of trading in the Treasury cash markets, transaction data is available only for a

subset of trades and only to those trading on a specific platform or venue. The staffs of the Treasury, Board, FRBNY, CFTC, and SEC are committed to continuing to appropriately enhance the information made public about the U.S. Treasury market. The authors of the report:

- Plan to conduct an assessment of the sufficiency of publicly available information on Treasury cash securities market transaction pricing and pre- and post-trade trading activity, including a review of possible post-trade transaction reporting by government securities broker-dealers and banks.
- Support efforts to enhance public reporting on U.S. Treasury market venue policies and services.

Inter-agency monitoring and oversight of the U.S. Treasury market

Activity related to U.S. Treasury trading often extends beyond individual regulatory boundaries; it encompasses not only the primary and secondary cash securities markets, but repo markets, futures contracts which reference U.S. Treasuries, and Treasury exchange-traded funds traded as equities. This diversity in trading venues and participants often leaves any individual regulator with only a partial view of Treasury risk transfer and price discovery. As firms are able to access multiple markets over very short time frames, they become ever more interconnected, resulting in significantly faster risk and information transmission. These trends call for continued cooperation among the official sector to ensure that the monitoring of market activity and liquidity is as effective and coordinated as possible.

The Inter-Agency Working Group for Treasury Market Surveillance (IAWG) was formed to improve monitoring and surveillance and strengthen interagency coordination with respect to the U.S. Treasury markets following the Salomon Brothers auction bidding scandal in 1992, and today consists of staff from the Treasury, Board, FRBNY, the CFTC, and the SEC.⁴² Since its

⁴² The IAWG was formed in 1992 by the Treasury, the SEC, and the Board, to strengthen monitoring, surveillance and interagency coordination in respect to the Treasury market. Its initial efforts were focused on developing a

inception it has been useful in providing a regular forum for the participating entities to collaborate on issues related to Treasury market structure, functioning, and participation, such as the events of October 15. In support of their ongoing respective responsibilities, the staff of the participating entities plan to work together to:

- Review, and enhance where necessary, the mission, responsibilities, resources, capabilities, and tools of the IAWG to help ensure that it meets the needs associated with effective monitoring and oversight of the U.S. Treasury market, while continuing to leverage the resources and mandates of its participating entities.
- Develop a standing multilateral information sharing agreement between the participating entities of the IAWG to allow access to – subject to appropriate protections and restrictions – confidential, non-public data, information, and analysis related to cash securities and futures markets on an ongoing, and event driven, basis.
- Assess the frequency and type of additional data reporting to the official sector necessary to continue to effectively monitor the functioning of the Treasury market and meet the IAWG mission.

framework for enhanced market surveillance for Treasury Securities. See U.S. DEPARTMENT OF THE TREASURY, SECURITIES AND EXCHANGE COMMISSION, AND BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM, JOINT REPORT ON THE GOVERNMENT SECURITIES MARKET (U.S. Government Printing Office, January 22, 1992) (the “1992 Report”), at xii-xiv. <http://www.treasury.gov/resource-center/fin-mkts/Documents/gsr92rpt.pdf> . See also THE U.S. DEPARTMENT OF THE TREASURY, SECURITIES AND EXCHANGE COMMISSION, AND BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM, JOINT STUDY ON THE GOVERNMENT SECURITIES MARKET (U.S. Government Printing Office, March 1998) (the “1998 Study”) at 14, http://www.treasurydirect.gov/instit/statreg/gsareg/gsareg_gsr98rpt.pdf. See also OFFICIAL SURVEILLANCE AND OVERSIGHT OF THE GOVERNMENT SECURITIES MARKET, William J. McDonough, FRBNY Quarterly Review, Spring 1992-93.

Appendix A: Participant-Type Classification and Trading Characteristics of PTFs and Bank-Dealers

Category	Typical Characteristics
Bank-Dealer	Bank owned dealer engaged in client trading and market making, mix of high and low frequency, directional trading, some of which may stem from client flows, SEC-registered broker-dealer.
Non-bank Dealer	Independent dealer, mainly trading for clients (agency investing) or market making, mix of high and low frequency, occasional directional trading stemming from client flows, SEC-registered broker-dealer.
Hedge Fund	Agency investing (rule 144A), no leverage restrictions, some automated market making but mostly low frequency trading, may be registered as broker-dealer, but does not have clients as in a typical broker-dealer business model.
Asset Manager	Agency investing for retail or institutional investors, limited leverage, long investment horizon, intermittent large directional flows spanning multiple trading sessions, low frequency trading.
Principal Trading Firm (PTF)	Principal investor, deploys proprietary automated trading strategies, low latency typically key element of trading strategies, may be registered as broker-dealer but does not have clients as in a typical broker-dealer business model.

The trading and quoting behavior of bank-dealers and PTFs exhibit different characteristics, though activity varies considerably by specific firm. The tables below show statistics across a range of indicators from October 15, with the wide range spanned by the 5th to 95th percentiles an indication of the broad set of trading strategies and tools employed within each participant group. In particular, some bank-dealer and hedge fund trading patterns exhibit characteristics of high frequency trading while many smaller PTFs clearly are not trading rapidly.

At the median, the data show that PTFs traded more frequently and, on average, in smaller size per trade than bank-dealers. The median PTF end-of-day positions were much smaller than that of the median bank-dealer, both in absolute terms and especially relative to trading volume. The ratio of the number of trades over the number of orders (known as the “fill ratio”) was also smaller for the median PTF than for the median bank-dealer, as would be expected given the high messaging rates exhibited by many PTFs. All of these PTF statistics are consistent with those on control days. This is likely because a significant share of PTF activity focuses on the provision of short-term liquidity on both sides of the market, and as such their high observed trading volume in the Treasury market does not translate into net changes in their positions across a trading session. An analysis of account-level data in the Treasury futures market over a number of days that include October 15 shows that more than 80 percent of trading in the 10-and 30-year contracts represented short-term intraday turnover.⁴³

⁴³ High observed trading volume in a market does not necessarily translate into net changes in overnight positions (defined as “open interest”). In various futures markets, the daily volume can be at least as large as the net positions carried overnight. As such, one cannot always interpret a day with a high trading volume as an indicator of changing end-investor interest.

Firm Classification Profile in Cash Treasuries (10 Year)

	<u>PTF</u>			<u>Bank-Dealer</u>		
	5%	Median	95%	5%	Median	95%
# of Firms		37			44	
Number of Orders	10	2,096	195,040	4.15	97	22,517
Trades Filled (count)	3.6	141	7,140	3	60	2,384
# of Fill Messages	3.8	190	7,310	5.15	96.5	3,004
Trade Volume (\$ millions)	4	292	18,707	11.3	314	8,403
Average Trade Size (\$ millions)	1	1.4	3.0	1.3	2.7	4.3
Absolute End-of-Day Position (scaled by total volume)	0	0.044	0.644	0.0105	0.190	0.888
Max Absolute Intraday Position (scaled by total volume)	0.006	0.153	0.644	0.08	0.283	0.914
Fill Ratio* (# of fills / # of orders)	0.004	0.153	0.740	0.063	0.649	0.853
Fraction of Aggressive Trades (count)	0.165	0.398	0.671	0	0.405	0.843
Fraction of Aggressive Trades (volume)	0.144	0.418	0.721	0.0	0.485	0.845

Firm Classification Profile in Treasury Futures (10 Year)

	<u>PTF</u>			<u>Bank-Dealer</u>		
	5%	Median	95%	5%	Median	95%
# of Firms		66			21	
Number of Orders	42.25	7,499	155,814	33	526	54,250
Trades Filled (count)	20.8	1,404	20,649	25	347	9,681
# of Fill Messages	59.3	2,260	53,230	110	4,142	24,832
Trade Volume (# of contracts)	180.3	9,535	325,839	467	59,141	228,092
Average Trade Size (# of contracts)	1.5	6.9	27.4	6.5	32.0	72.7
Absolute End-of-Day Position (scaled by total volume)	0	0.011	0.415	0.015	0.083	0.289
Max Absolute Intraday Position (scaled by total volume)	0.001	0.021	0.341	0.008	0.089	0.409
Fill Ratio* (# of fills / # of orders)	0.019	0.41	0.96	0.084	0.75	0.91
Fraction of Aggressive Trades (count)	0.024	0.27	0.73	0.15	0.51	0.73
Fraction of Aggressive Trades (volume)	0.027	0.28	0.74	0.28	0.54	0.76
Fraction of Automated Trades		94.8%			33.8%	
Fraction of Automated Messages		99.6%			82.8%	

Appendix B: Cross-Market Activity between Cash and Futures Markets

To illustrate the incidence of cross-market activity, an index was developed to illustrate the level of activity occurring in a coincident manner across different markets. Figures B.1-B.6 show the cross market activity index between the 10-year cash and various futures markets, with activity for the top 10 bank-dealers shown in the left hand column, and activity for PTFs in the right hand column. October 15 is plotted in red and the mean daily index for the April 2014 control days is shown in blue.

The cross market activity for the 10-year note and 10-year note futures contract indicates that trades by the top 10 PTFs on the CME are frequently followed by trades by the same group of firms in the cash market with a lag of roughly 5 milliseconds (Figure B.2). The time gap between these trades is just above the theoretical minimum latency between the Chicago area, where the CME matching engine is located, and eastern New Jersey, where the cash platform matching engines are located. Similarly but less frequently the inverse occurs, with trades in the cash market by the largest PTFs followed by trades at the CME by the same group of firms with a similar level of latency. For bank-dealers, the activity is much less pronounced. But in both cases it is clear that the cross market activity is elevated on October 15 compared to the control days, which may be consistent with the hypothesis that more trading opportunities arise between the two markets at times of extreme volatility and high volume.

There is little evidence of heightened cross-market activity between the Treasury market and markets that are not as directly related to interest rates, such as the S&P 500 E-Mini (ES) futures (Figures B.5 and B.6). Overall, the observed cross-market activity patterns appear consistent with known automated trading strategies that involve a nearly instantaneous response to common trading signals or that seek to arbitrage short-lived opportunities across related interest-rate products. As noted, such linkages are witnessed in other markets as well—for example between equity index futures and the cash equity market.

Appendix C: Potential Risks of Automated Trading

Increases in the use of automated trading by a wide range of market participants has helped reduce costs and increase market efficiency for many market participants, but has introduced or changed a number of risks:

Operational risks: Such risks are inherent in all financial transactions but of particular concern with automated trading given the potential speed of execution. Operational risks range from malfunctioning and incorrectly deployed algorithms to algorithms reacting to inaccurate or unexpected data.

Market liquidity risks: Even when a firm executes its strategy perfectly, risks to market liquidity may arise from abrupt changes in trading strategies. Such risks are naturally greater when such shifts occur at firms with higher trading activity and/or if firms react to an event in a similar manner.

Market integrity risks: Market integrity is undermined by acts of manipulation or attempts thereof, fraud, disruptive trading, such as spoofing, and other unlawful trade practices, such as wash sales and pre-arranged trading.⁴⁴ Such risks are not new to financial markets, but automated trading can provide traders with new tools to engage in such unlawful conduct, for many reasons, including creating false impressions of market depth, trading volume, and prices.

Transmission risks: Data from October 15 and other days reveal a high and consistent presence of cross market trading between the futures exchange and the cash interdealer market platforms. Such trading is generally beneficial at promoting the quick incorporation

⁴⁴ “Spoofing” involves entering orders with the intent to cancel them before execution and may be undertaken for various reasons, including to provide a misleading view of depth. “Wash sales” for purposes of the futures/derivatives markets are defined in footnote 31, *supra*.

of fundamental information into prices across markets, but can sometimes result in the transmission of shocks based on erroneous orders or other idiosyncratic factors.⁴⁵

Clearing and settlement risks: Traditionally, firms trading on the interdealer platforms have cleared through the Fixed Income Clearing Corporation (FICC), which offers central clearing services for cash Treasury securities. However, as PTFs have gained access to the platforms, they have remained outside the FICC membership and clear with each other either bilaterally, or through a prime broker for trades executed with a FICC member.⁴⁶ The significance of trading volume of firms outside the FICC membership—now larger in aggregate than that of FICC netting members—raises the question of whether trades cleared for non-CCP members are processed as prudently as those for firms inside the CCP. Trades cleared outside the CCP may not be subject to the same level of settlement risk mitigation techniques such as margin collection, disciplined clearing fund balance requirements, and pre-defined loss sharing arrangements.

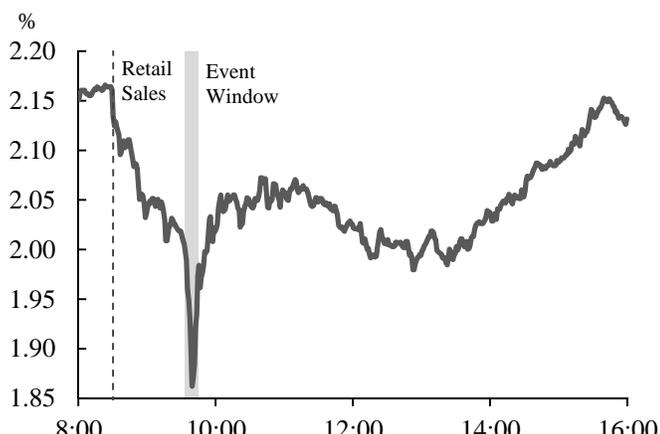
Risks to effective risk management: The speed of trade execution might make critical risk mitigation devices, such as trade and position monitoring systems or margin, less effective. For example, margin could be insufficient if an exposure grew faster than margin could be collected.

⁴⁵ Because PTFs are privately held and generally face lighter regulation than registered broker-dealers, limited financial information is available about many PTFs, including about their financial linkages—and thus their potential to transmit risk—to traditional financial institutions.

⁴⁶ Such a prime brokerage relationship facilitates clearance between a non-FICC member and a FICC member, as the prime broker is a netting member of the FICC. The use of prime brokers by PTFs is facilitated by the cash market trading venues which act as “introducing brokers” to the prime broker, assuming the credit risk of the PTFs which are active on their platform.

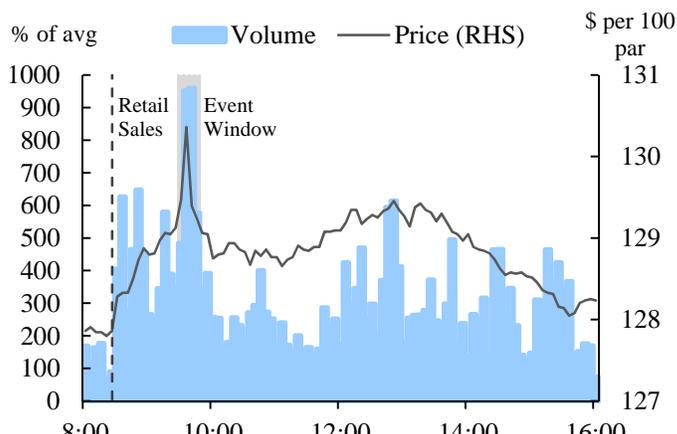
Section 2 Figures

Figure 2.1: 10-Year Treasury Yield on October 15 (Cash)



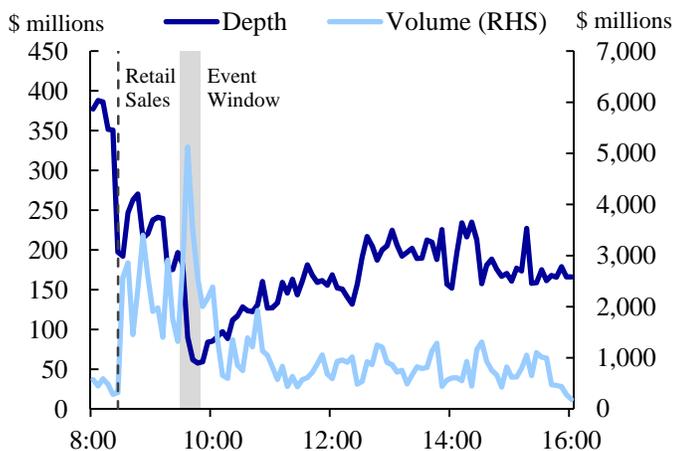
Note: 1-minute observations; Yield is inversely related to price; Unless otherwise noted, intraday figures show October 15 US trading hours
Source: Staff calculations, based on data from Bloomberg.

Figure 2.2: Intraday Price and Volume in 10-Year Treasury (Futures)



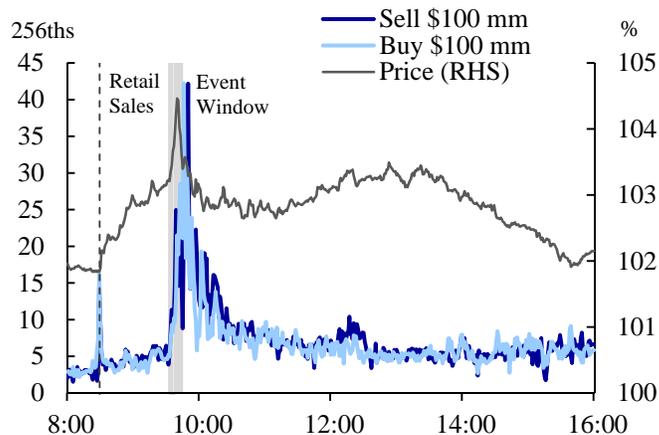
Note: 1-minute intervals; Volume as percent of average of previous 30 trading days
Source: Staff calculations, based on data from Bloomberg.

Figure 2.3: 10-Year Volume and Market Depth (Cash)



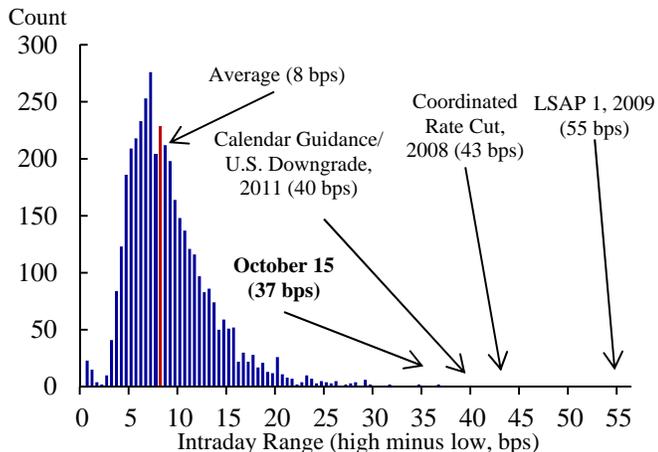
Note: 5-minute intervals; Sum of top 3 levels
Source: Staff calculations, based on data from BrokerTec.

Figure 2.4: Cost of Conducting Trade (Cash)



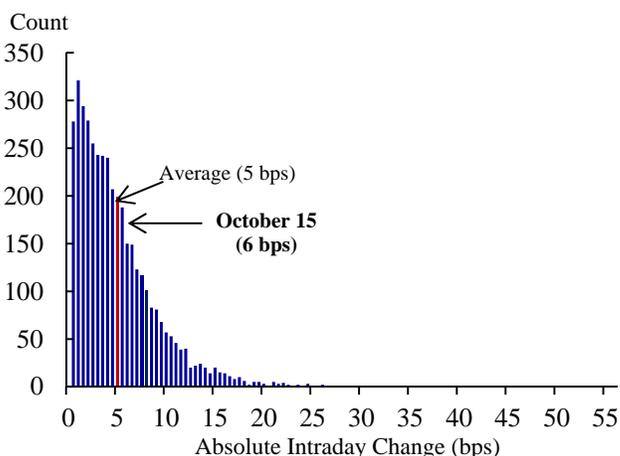
Note: 1-minute intervals; Spread between best bid/ask and volume-weighted average price to complete trade; \$ per \$100 par
Source: Staff calculations, based on data from BrokerTec.

Figure 2.5: Historical Intraday Yield Ranges for 10-Year Treasury (Cash)



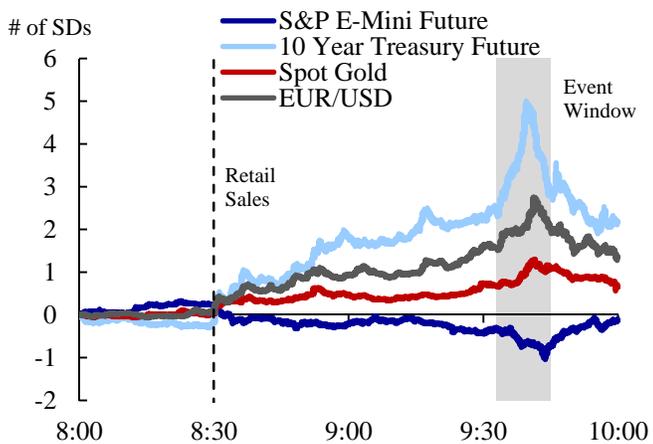
Note: Daily observations; 10/1998-10/2014
Source: Staff calculations, based on data from Bloomberg.

Figure 2.6: Historical Full Day Yield Changes for 10-Year Treasury (Cash)



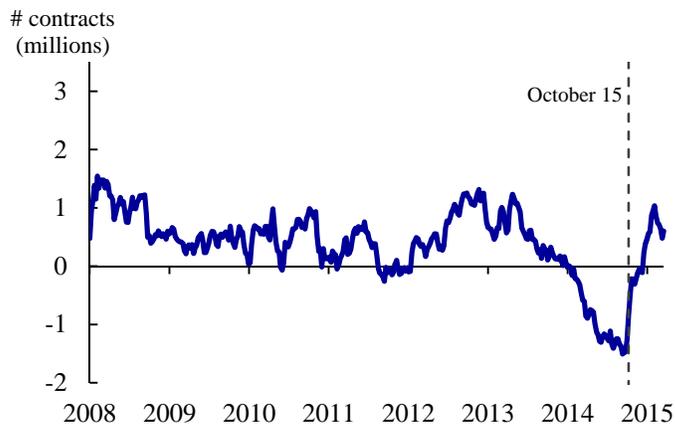
Note: Daily observations; 10/1998-10/2014
Source: Staff calculations, based on data from Bloomberg.

Figure 2.7: Cross-Asset Performance



Note: 5-second observations; Daily standard deviation of returns since 2006; Front month contract
 Source: Staff calculations, based on data from Bloomberg.

Figure 2.8: Leveraged Funds Net Positioning in 3-Month Eurodollar Futures



Note: Weekly observations
 Source: Staff calculations, based on data from CFTC (Current Traders in Financial Futures)

Section 3 Tables and Figures

**Table 3.1: Volume on October 15 by Firm Type
(Cash)**

Firm Type	5 Year	10 Year	30 Year
Asset Manager	0.0%	0.0%	0.0%
Bank/Dealer	30.1%	35.7%	40.6%
Hedge Fund	9.0%	5.6%	6.0%
PTF	57.1%	54.8%	51.4%
Non-bank Dealer	3.9%	3.9%	2.0%
Total Volume (\$ millions)	150,386	123,198	21,915

Note: Unless otherwise noted, tables are based on entire trading session, 19:30 prev. day – 17:30 ET
Source: Staff calculations, based on data from BrokerTec.

**Table 3.2: Volume on October 15 by Firm Type
(Futures)**

Firm Type	5 Year	10 Year	Long Bond
Asset Manager	4.0%	3.3%	2.3%
Bank/Dealer	11.5%	17.6%	10.9%
Hedge Fund	7.8%	8.3%	8.7%
PTF	69.3%	59.4%	64.9%
Non-Bank Dealer	1.4%	2.4%	2.1%
Other	6.0%	8.9%	11.2%
Total Volume (\$ millions)	498,546	779,519	229,408

Note: Unless otherwise noted, tables are based on entire trading session, 18:00 prev. day – 16:00 ET; Front month contract
Source: Staff calculations, based on data from CME Group.

**Table 3.3: Volume on Control Days by Firm Type
(Cash)**

Firm Type	5 Year	10 Year	30 Year
Asset Manager	0.1%	0.1%	0.0%
Bank/Dealer	38.4%	34.7%	40.5%
Hedge Fund	4.8%	3.9%	9.4%
PTF	52.6%	56.3%	46.6%
Non-bank Dealer	4.2%	5.0%	3.5%
Avg Daily Volume (\$ millions)	53,077	44,088	9,860

Note: Control days: 04/02/2014 - 04/17/2014
Source: Staff calculations, based on data from BrokerTec.

**Table 3.4: Volume on Control Days by Firm Type
(Futures)**

Firm Type	5 Year	10 Year	Long Bond
Asset Manager	5.2%	3.6%	3.5%
Bank/Dealer	17.0%	15.8%	9.2%
Hedge Fund	11.6%	15.3%	13.6%
PTF	52.4%	51.1%	59.1%
Non-Bank Dealer	2.9%	2.0%	2.4%
Other	10.9%	12.2%	12.3%
Avg Daily Volume (\$ millions)	132,087	248,373	61,280

Source: CME Group

**Table 3.5: Message Counts on October 15 by Firm Type
(Cash)**

Firm Type	5 Year	10 Year	30 Year
Bank/Dealer	15.1%	23.6%	13.8%
Hedge Fund	1.9%	1.6%	0.2%
Non-bank Dealer	0.6%	0.5%	0.2%
PTF	82.3%	74.3%	85.8%
Total (# of messages)	2,786,237	2,700,735	1,637,309

Note: Includes all messages
Source: Staff calculations, based on data from BrokerTec.

**Table 3.6: Message Counts on October 15 by Firm Type
(Futures)**

Firm Type	5 Year	10 Year	Long Bond
Bank/Dealer	4.8%	10.2%	8.0%
Hedge Fund	6.1%	2.6%	4.8%
Non-bank Dealer	0.4%	0.2%	0.3%
PTF	82.0%	79.1%	80.1%
FCM	1.9%	2.6%	2.1%
Other	4.9%	5.3%	4.7%
Total (# of messages)	2,069,213	2,853,563	1,865,663

Note: Includes all new, modify, and delete messages
Source: Staff calculations, based on data from CME Group.

Table 3.7: Firm Concentration in 10-Year Treasury (Cash)

	<u>10/15/2015</u>		<u>Control Days</u>	
	Bank/Dealer	PTF	Bank/Dealer	PTF
# of Participants	44	37	45	40
Top 10 Volume Share	79%	94%	77%	93%
Top 10 HHI	0.11	0.23	0.11	0.23
Firm Type HHI	0.07	0.20	0.07	0.20
All Firms HHI	0.07		0.07	

Note: Control days: 04/02/14 – 04/17/14; HHI is Herfindahl-Hirschman Index
Source: Staff calculations, based on data from BrokerTec.

Table 3.9: Self-Trading in 10-Year as % of Type Volume (Cash)

	<u>10/15/2015</u>	<u>Control Days</u>
Bank/Dealer	1.4%	1.3%
Hedge Fund	1.2%	1.0%
Non-bank Dealer	0.0%	0.7%
PTF	6.7%	9.0%
All Firms	4.2%	5.6%

Note: Control days: 04/02/2014 - 04/17/2014

Source: Staff calculations, based on data from BrokerTec.

Table 3.8: Firm Concentration in 10-Year Treasury (Futures)

	<u>10/15/2015</u>		<u>Control Days</u>	
	Bank/Dealer	PTF	Bank/Dealer	PTF
# of Participants	21	65	21	65
Top 10 Volume Share	89%	83%	91%	86%
Top 10 HHI	0.11	0.22	0.11	0.18
Firm Type HHI	0.09	0.15	0.10	0.14
All Firms HHI	0.05		0.04	

Note: Control days: 04/02/14 – 04/17/14; Front month contract
Source: Staff calculations, based on data from CME Group.

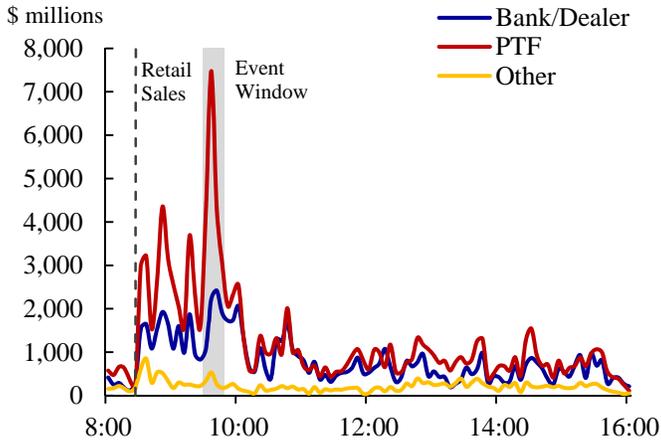
Table 3.10: Self-Trading in 10-Year as % of Type Volume (Futures)

	<u>10/15/2015</u>	<u>Control Days</u>
Asset Manager	0.10%	0.00%
Bank/Dealer	0.60%	0.40%
Hedge Fund	0.20%	0.70%
Non-Bank Dealer	0.30%	0.20%
PTF	6.40%	4.40%
All Firms	4.20%	2.70%

Note: Control days: 04/02/2014 - 04/17/2014; Front month contract

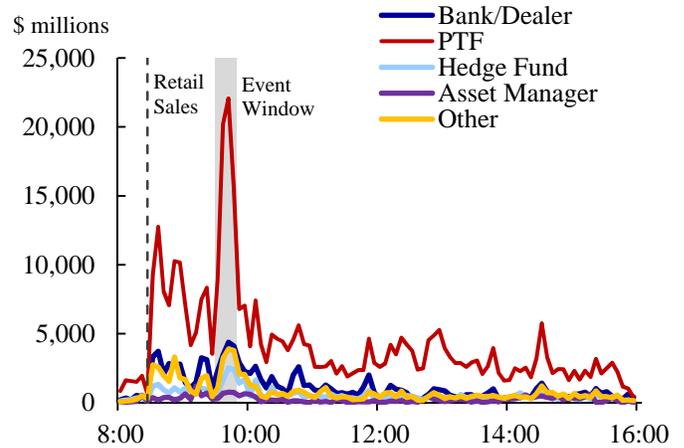
Source: Staff calculations, based on data from BrokerTec.

Figure 3.1: 10-Year Intraday Volume by Firm Type (Cash)



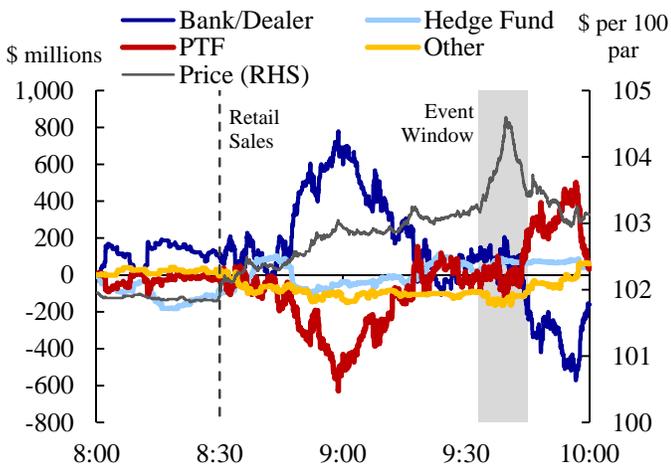
Note: 5-minute intervals; Gross volume
Source: Staff calculations, based on data from BrokerTec.

Figure 3.2: 10-Year Intraday Volume by Firm Type (Futures)



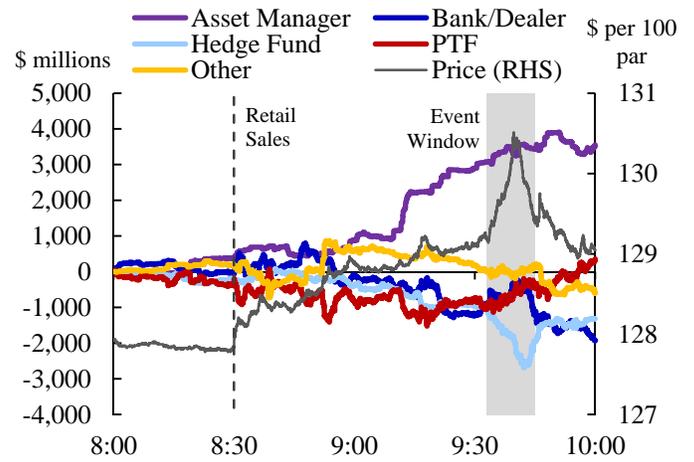
Note: 5-minute intervals; Gross volume; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.3: 10-Year Net Position by Type (Cash)



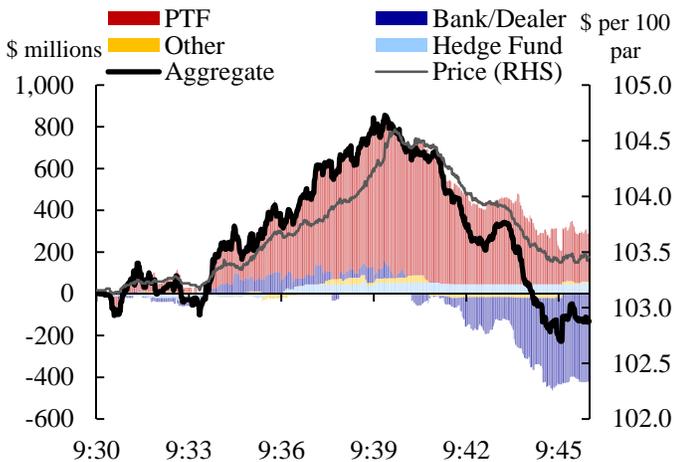
Note: 1-second observations
Source: Staff calculations, based on data from BrokerTec.

Figure 3.4: 10-Year Net Position by Type (Futures)



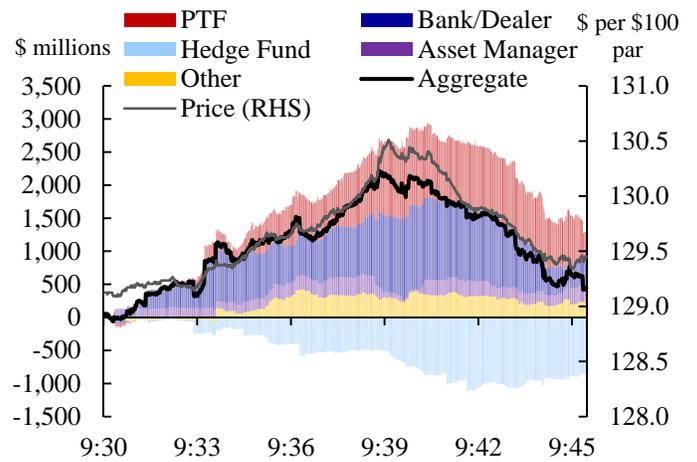
Note: 1-second observations; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.5: 10-Year Cumulative Net Aggressive Volume (Cash)



Note: Stacked 1-second observations
Source: Staff calculations, based on data from BrokerTec.

Figure 3.6: 10-Year Cumulative Net Aggressive Volume (Futures)



Note: Stacked 1-second observations; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.7: 10-Year Cumulative Net Passive Volume (Cash)

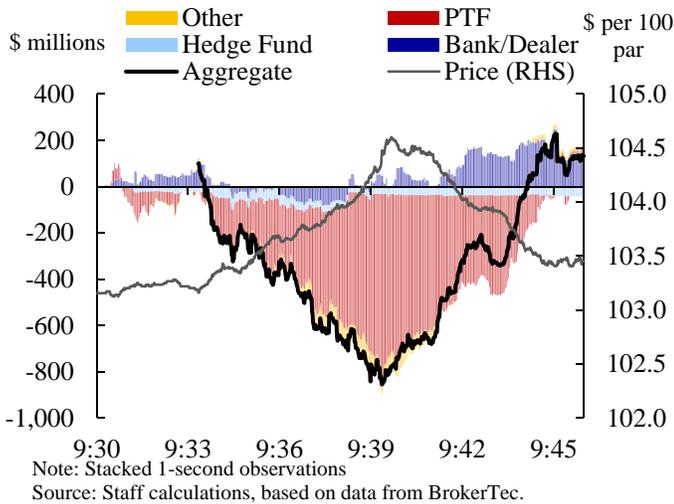


Figure 3.8: 10-Year Cumulative Net Passive Volume (Futures)

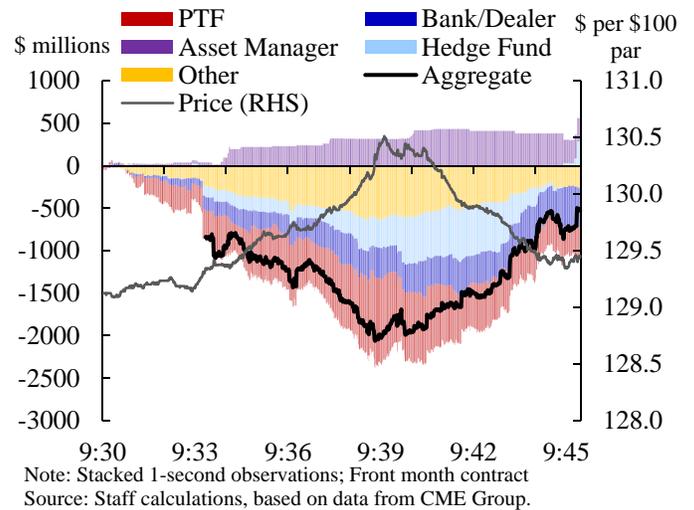


Figure 3.9: 10-Year PTF Cumulative Net Aggressive Volume (Cash)

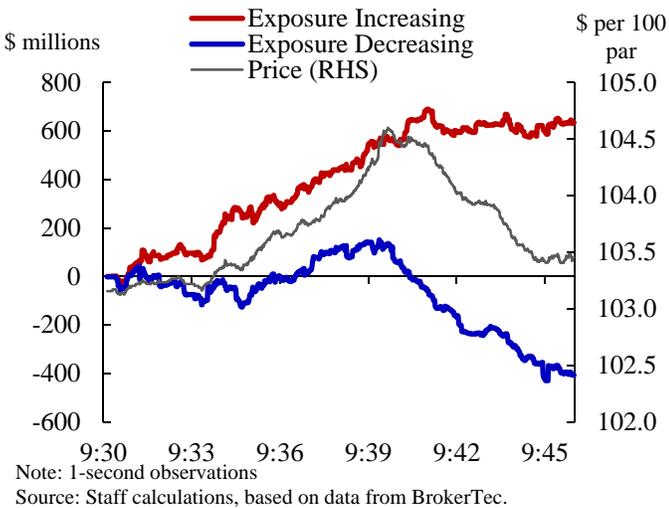


Figure 3.10: 10-Year PTF Cumulative Net Aggressive Volume (Futures)

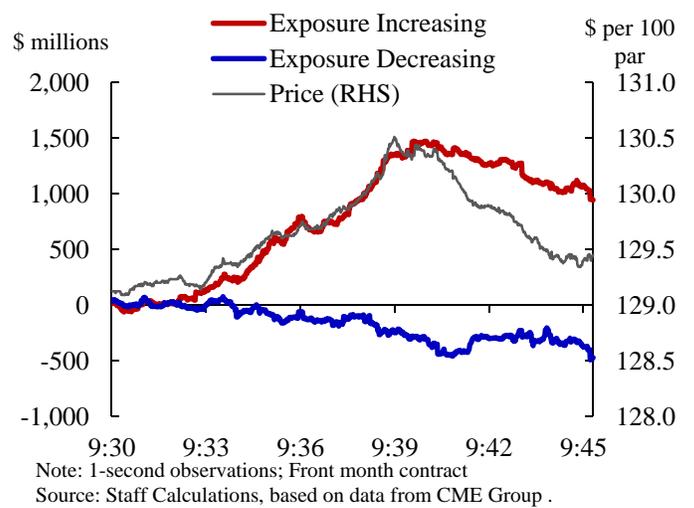


Figure 3.11: 10-Year Bank/Dealer Cumulative Net Aggressive Volume (Cash)

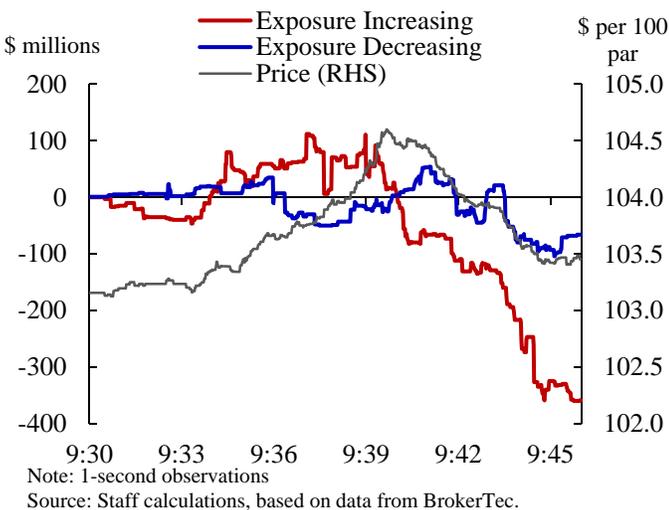


Figure 3.12: 10-Year Bank/Dealer Cumulative Net Aggressive Volume (Futures)

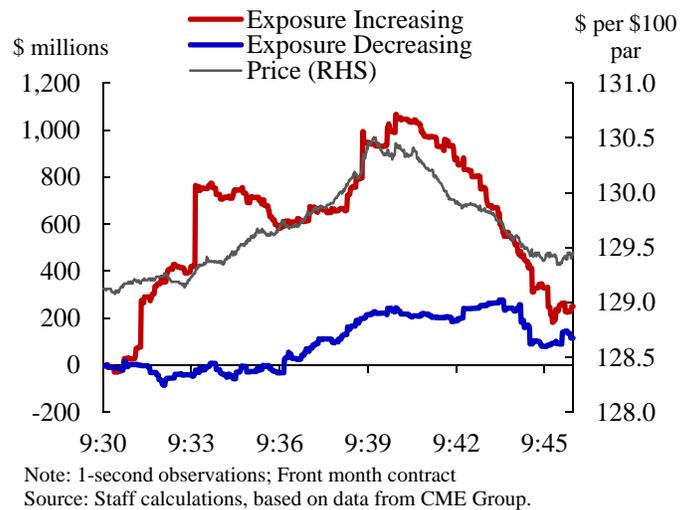
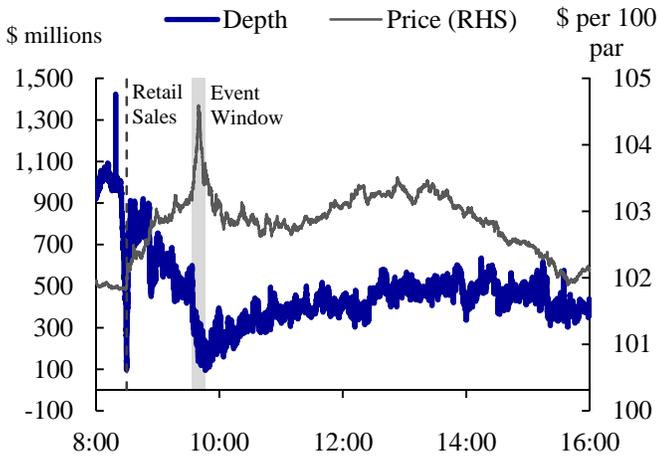
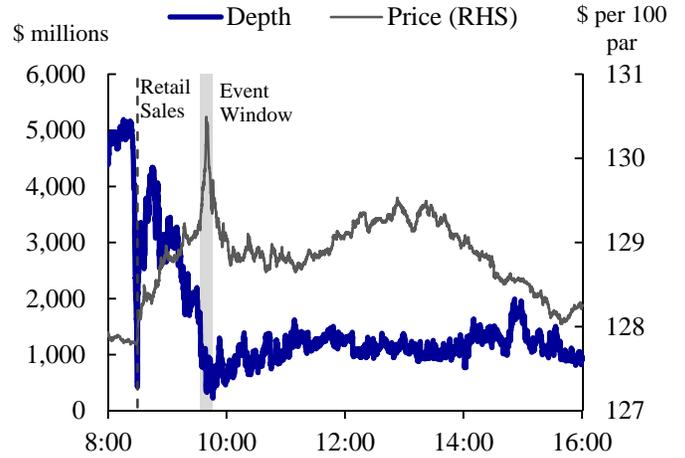


Figure 3.13: 10-Level Market Depth (Cash)



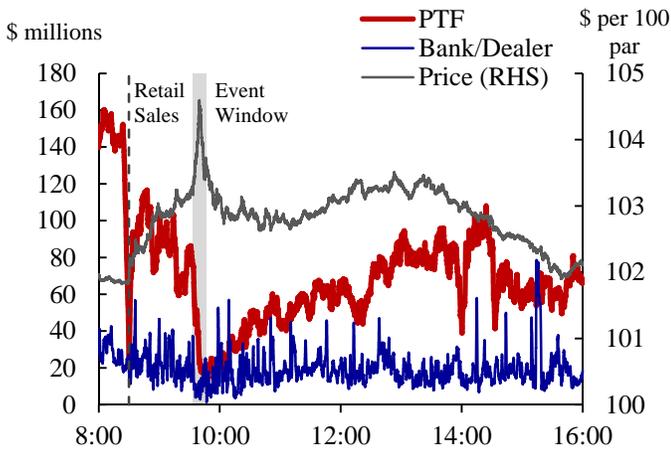
Note: 1-second observations; Sum of top 10 levels
Source: Staff calculations, based on data from BrokerTec.

Figure 3.14: 10-Level Market Depth (Futures)



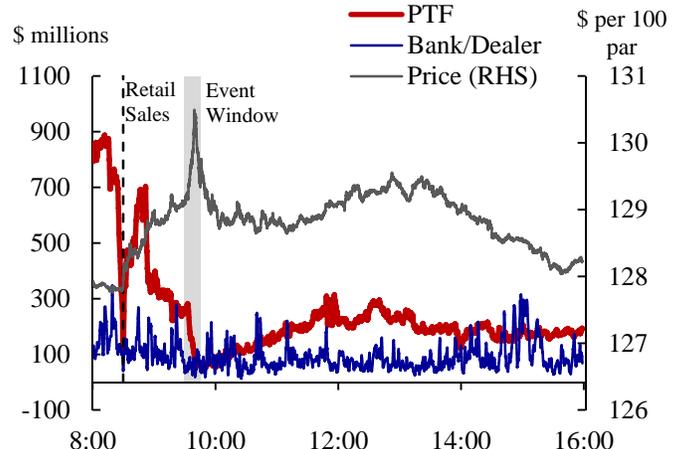
Note: 1-second observations; Sum of top 10 levels; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.15: Depth at Top 3 Levels by Type (Cash)



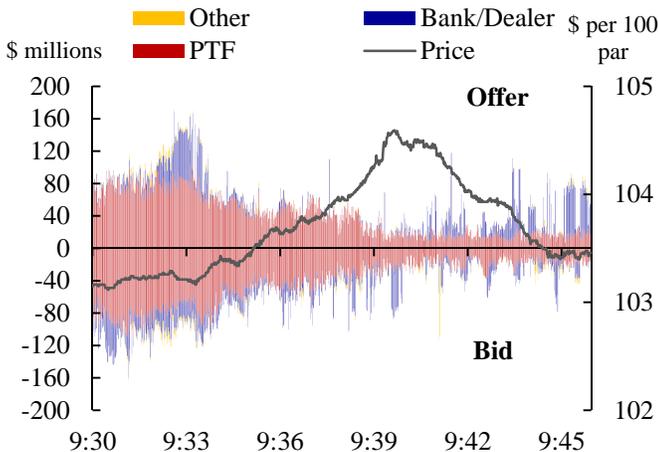
Note: 1-minute moving average; Sum of top 3 levels
Source: Staff calculations, based on data from BrokerTec.

Figure 3.16: Depth at Top 3 Levels by Type (Futures)



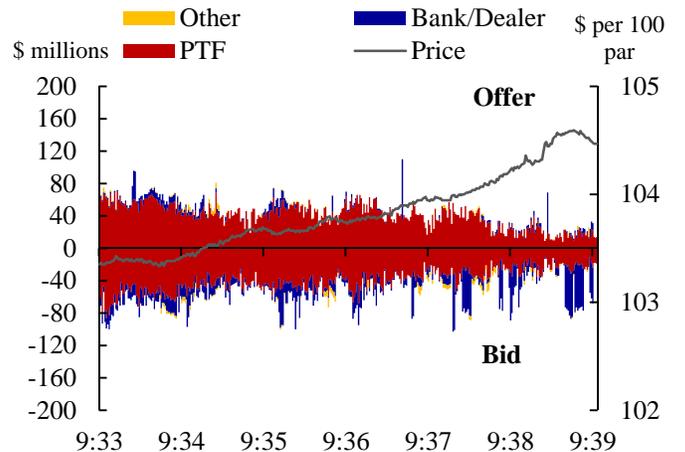
Note: 1-minute moving average; Sum of top 3 levels; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.17: Depth by Type during Event Window (Cash)



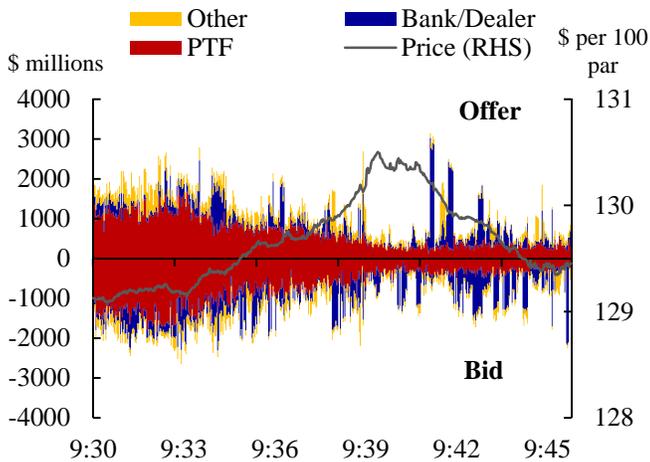
Note: Stacked 1-second observations; Top 3 levels
Source: Staff calculations, based on data from BrokerTec.

Figure 3.18: Depth by Type during First Part of Event Window (Cash)



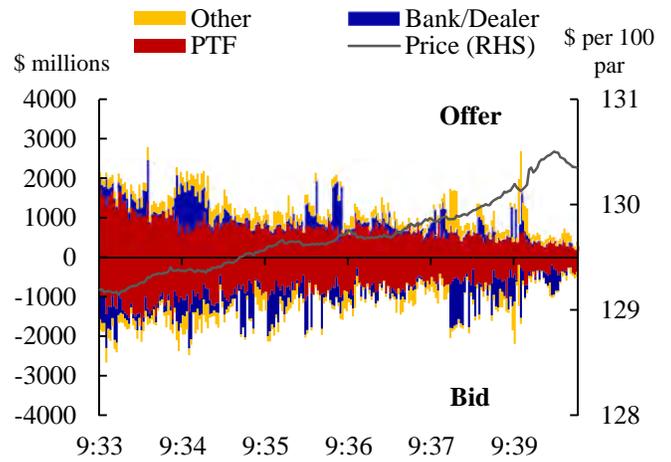
Note: Stacked 1-second observations; Top 3 levels; Front month contract
Source: Staff calculations, based on data from BrokerTec.

Figure 3.19: 10-Year Depth by Type during Event Window (Futures)



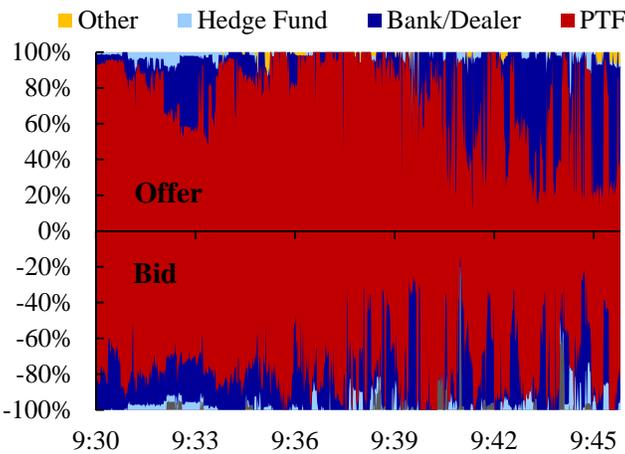
Note: Stacked 1-second observations; Top 3 levels
Source: Staff calculations, based on data from CME Group.

Figure 3.20: 10-Year Depth by Type during First Part of Event Window (Futures)



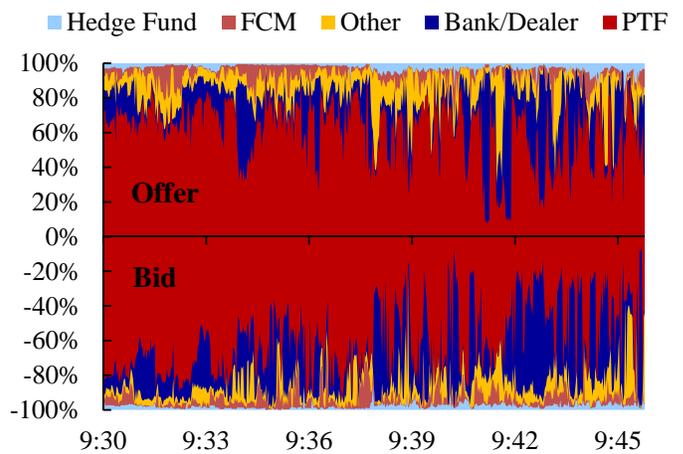
Note: Stacked 1-second observations; Top 3 levels; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.21: 10-Year Share of Depth by Type during Event Window (Cash)



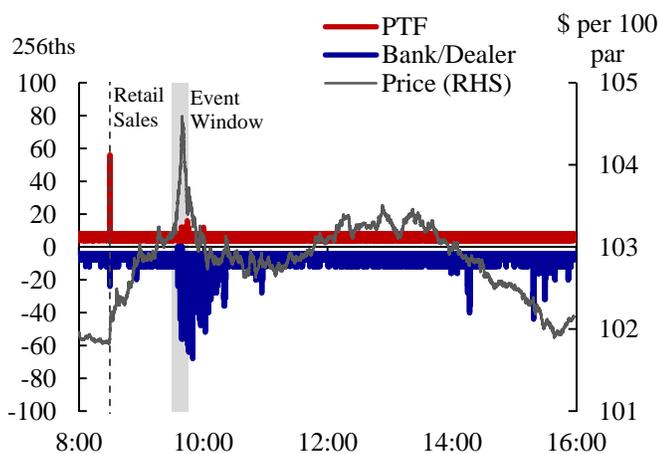
Note: 1-second observations; Top 3 levels
Source: Staff calculations, based on data from BrokerTec.

Figure 3.22: 10-Year Share of Depth by Type during Event Window (Futures)



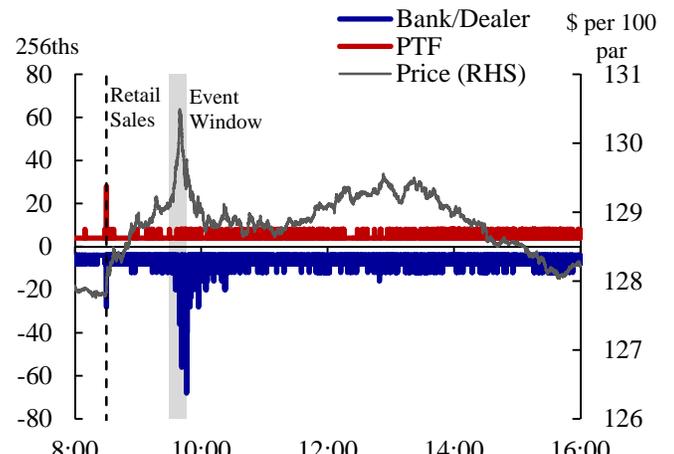
Note: 1-second observations; Top 3 levels; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.23: 10-Year Bid/Ask Spreads by Type (Cash)



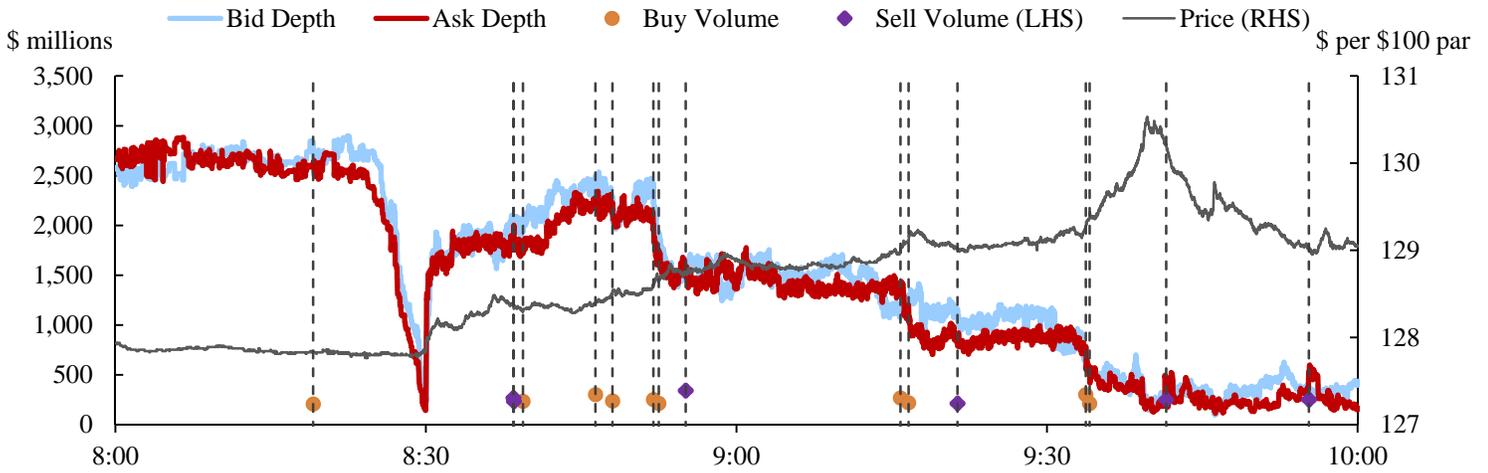
Note: 1-second observations; \$ per \$100 par
Source: Staff calculations, based on data from BrokerTec.

Figure 3.24: 10-Year Bid/Ask Spread by Type (Futures)



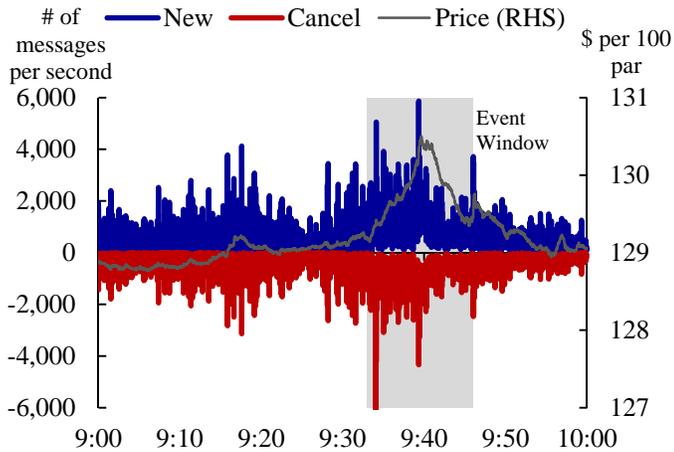
Note: 1-second observations; \$ per \$100 par; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.25: 10-Year Timeline of Large Aggressive Trades (Futures)



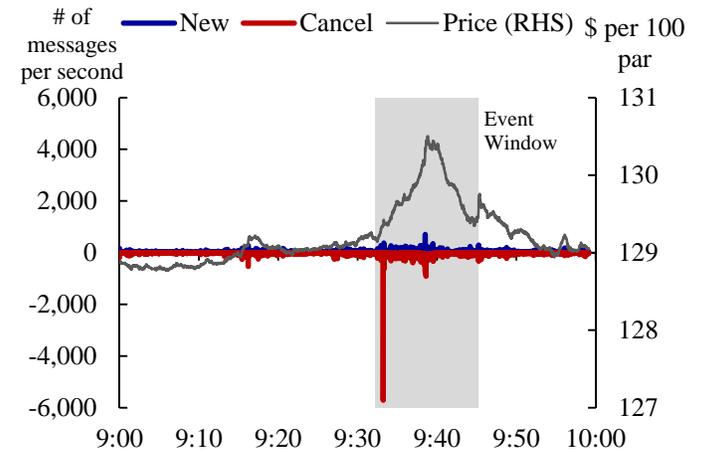
Note: Trades > 2000 contracts; \$200 million notional; Top 10 levels; Front month contract
Source: Staff calculations, based on data from CME Group.

Figure 3.26: Messages Processed by Matching Engine by Message Type (Futures)



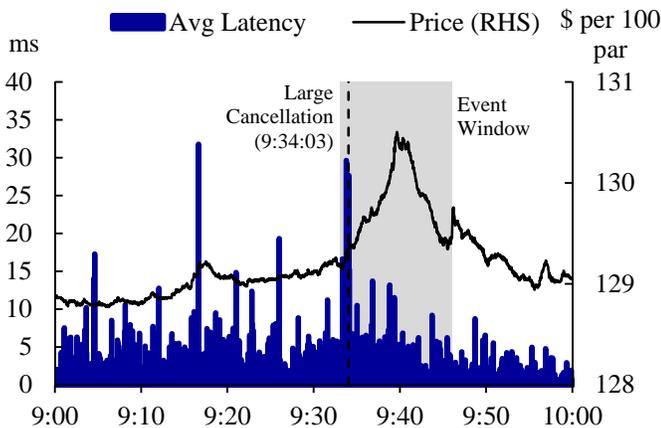
Note: 1-second intervals; Includes all US Treasury futures contracts
Source: Staff calculations, based on data from CME Group.

Figure 3.27: Messages Processed by Matching Engine Outside Visible 10 Levels (Futures)



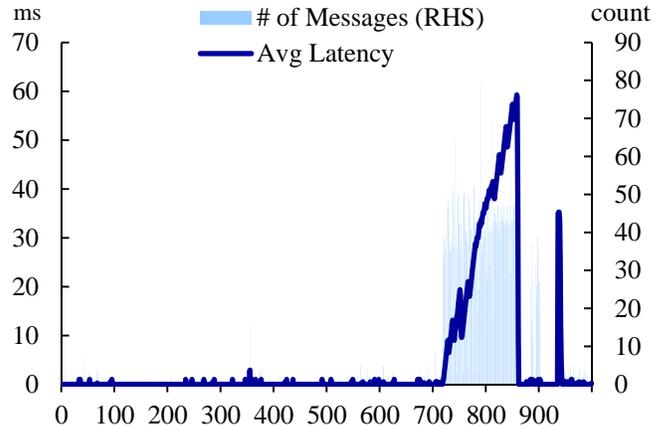
Note: 1-second intervals; Includes all US Treasury futures contracts
Source: Staff calculations, based on data from CME Group.

Figure 3.28: Latency on US Treasury Futures Matching Engine (Futures)



Note: 1-second intervals; Includes new, modify, and delete messages; Includes all US Treasury futures contracts
Source: Staff calculations, based on data from CME Group.

Figure 3.29: Latency in US Treasury Futures Matching Engine at 9:34:03 (Futures)



Note: 1-millisecond intervals; Include new, modify, delete; All US Treasury futures contracts
Source: Staff calculations, based on data from CME Group.

Figure 3.30: 10-Year Total Market Depth (Futures)

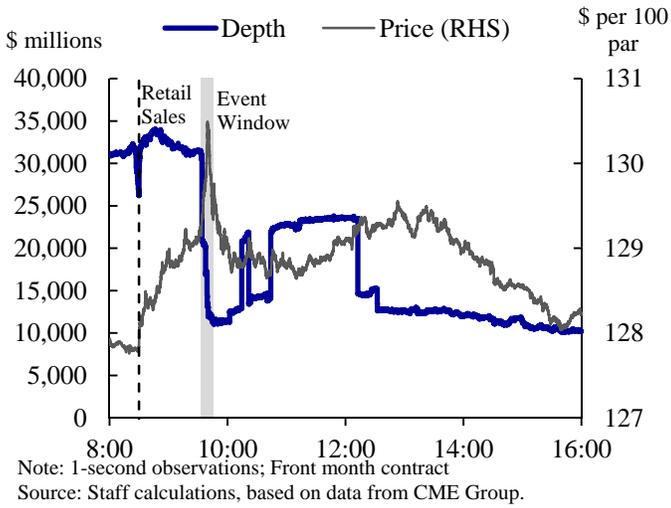


Figure 3.31: Self Trades as % of Total Volume

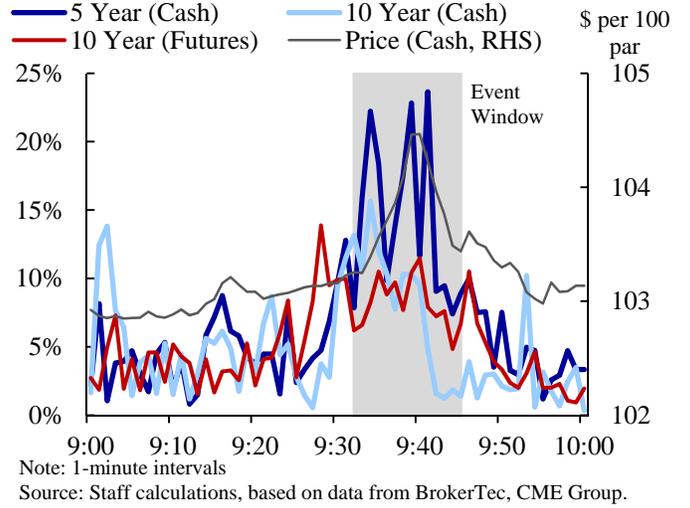


Figure 3.32: 10-Year Cumulative Net Aggressive Self Trade Volume (Cash)

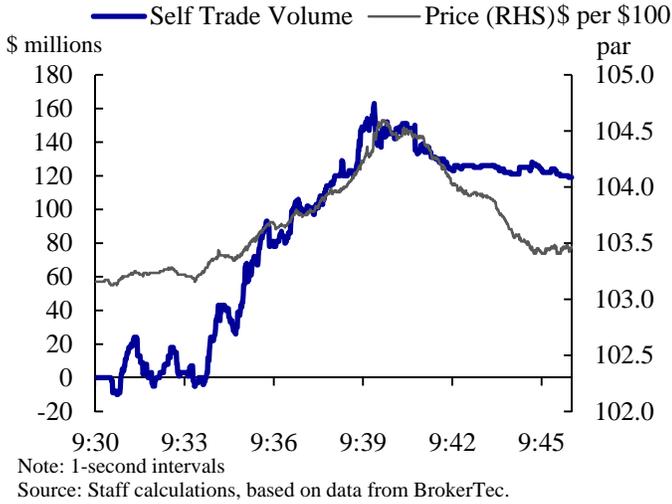
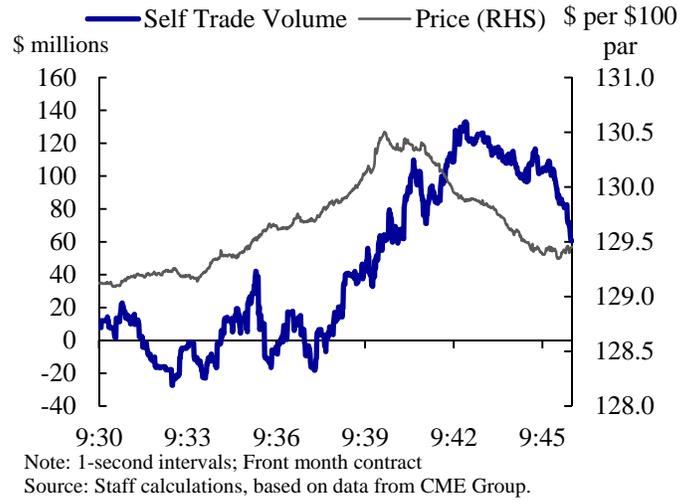
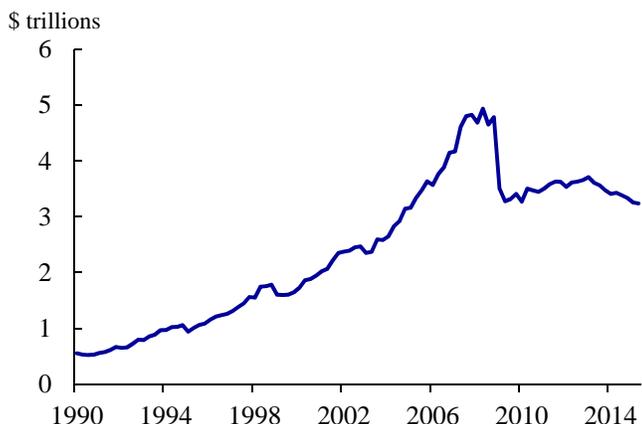


Figure 3.33: 10-Year Cumulative Net Aggressive Self Trade Volume (Futures)



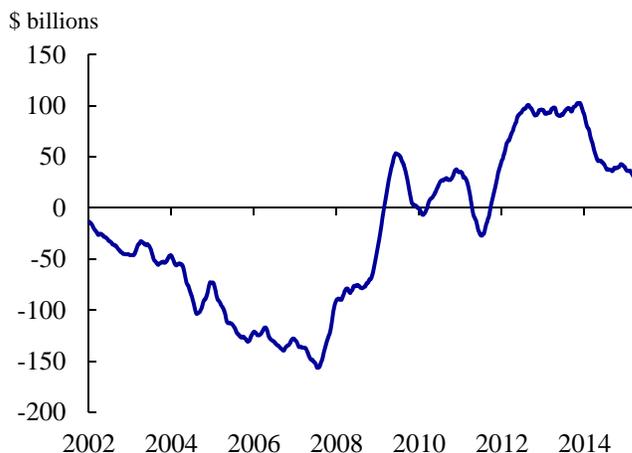
Section 4 Figures

Figure 4.1: Financial Assets of Security Brokers and Dealers



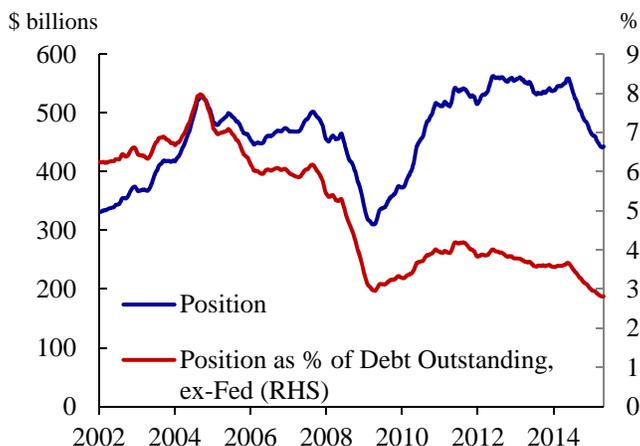
Note: Quarterly observations; Total financial assets of security brokers and dealers as reported in the financial accounts of the United States
Source: Staff calculations, based on data from Federal Reserve Board.

Figure 4.2: Net Treasury Positions of Primary Dealers



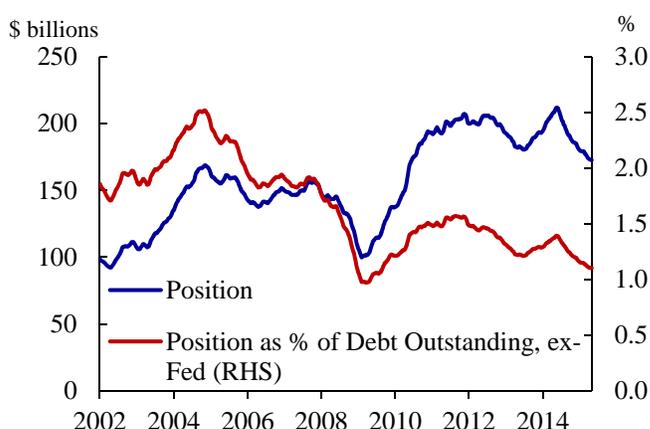
Note: 4-week moving average
Source: Staff calculations, based on data from FRBNY.

Figure 4.3: Gross Treasury Positions of Primary Dealers



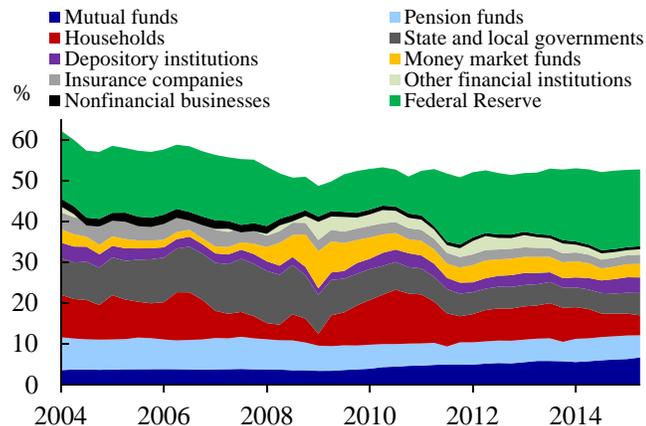
Note: 4-week moving average; Sum of dealers' short and long positions
Source: Staff calculations, based on data from FRBNY.

Figure 4.4: Estimated Treasury Market-Making Positions of Primary Dealers



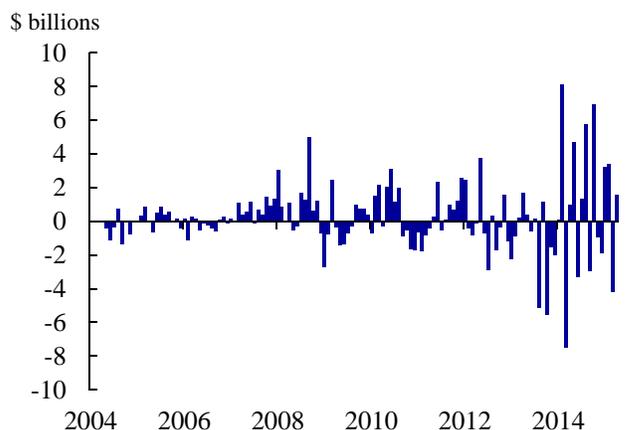
Note: 4-week moving average; Smaller of each dealer's short and long position in each reporting bucket, aggregated across dealers and buckets
Source: Staff calculations, based on data from FRBNY.

Figure 4.5: Ownership of Treasury Debt by Investor Group



Note: Mutual funds includes closed-end funds and exchange-traded funds; Pension funds includes government retirement funds
Source: Staff calculations, based on data from Federal Reserve Board.

Figure 4.6: Government Bond Fund Flows



Note: Total net monthly flows; Some funds own agency debt securities and MBS in addition to Treasury securities
Source: Staff calculations, based on data from Morningstar.

Figure 4.7: Treasury Benchmark Bid-Ask Spreads (Cash)

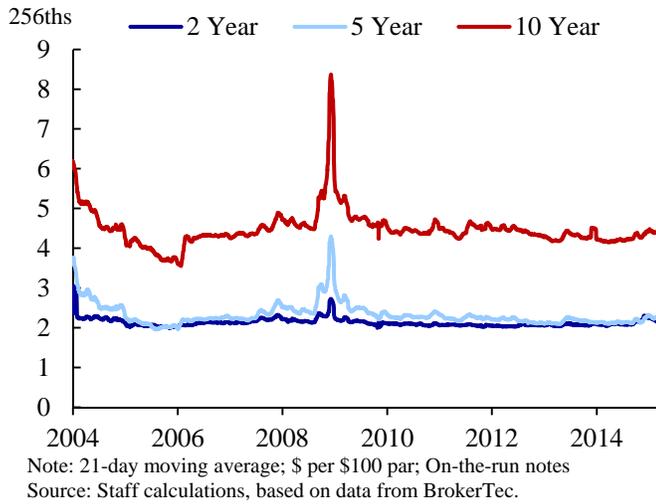


Figure 4.8: Treasury Yield Curve Fitting Errors

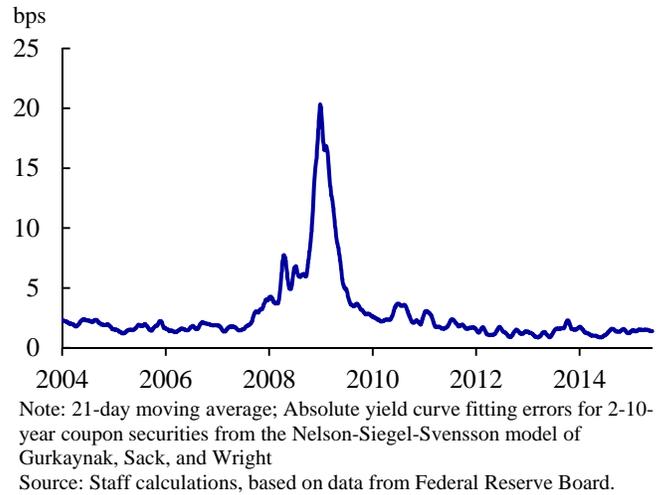


Figure 4.9: Primary Dealer Treasury Volumes

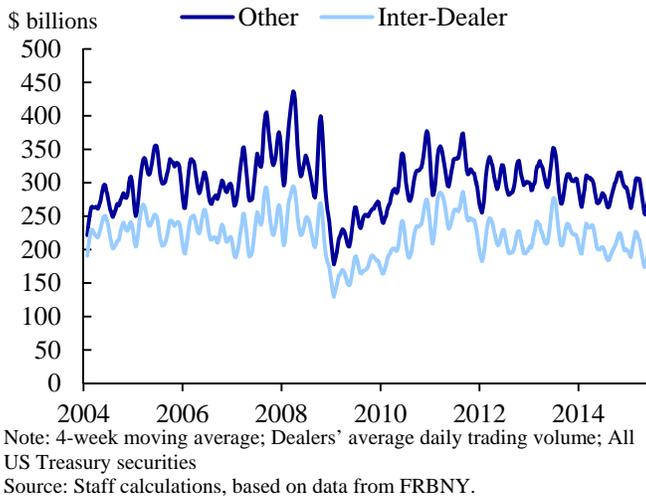


Figure 4.10: Treasury Benchmark Volume (Cash)

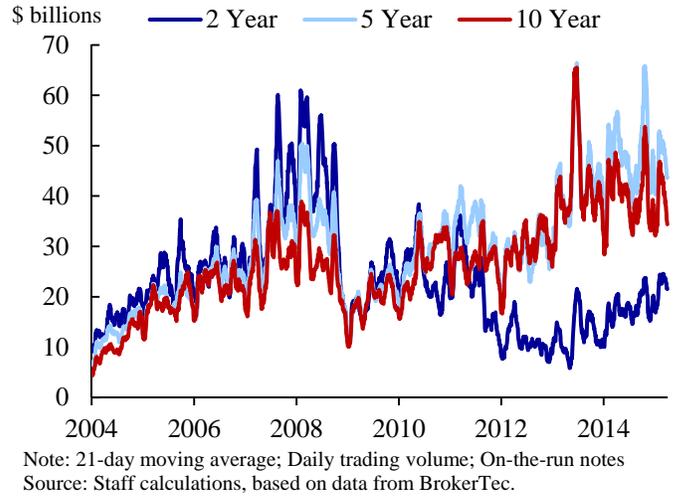


Figure 4.11: Treasury Active Contract Volume (Futures)

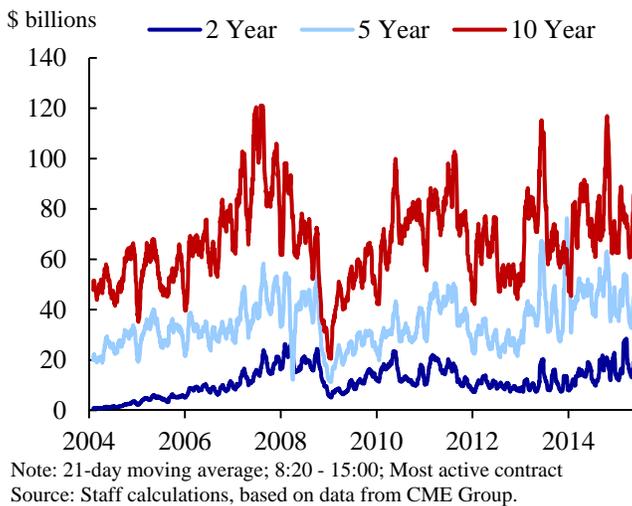


Figure 4.12: Benchmark Order Book Depth (Cash)

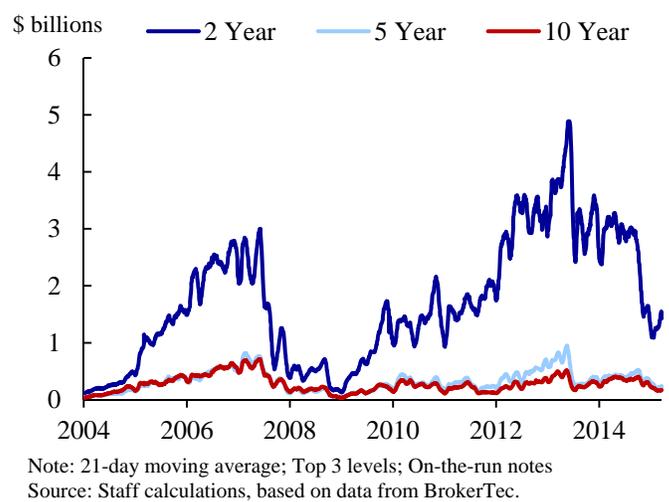
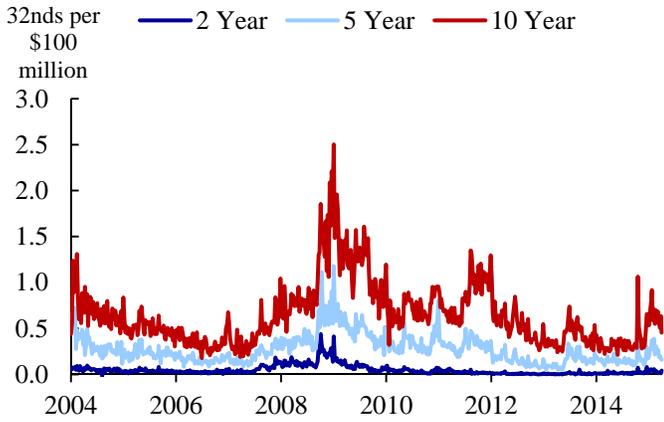
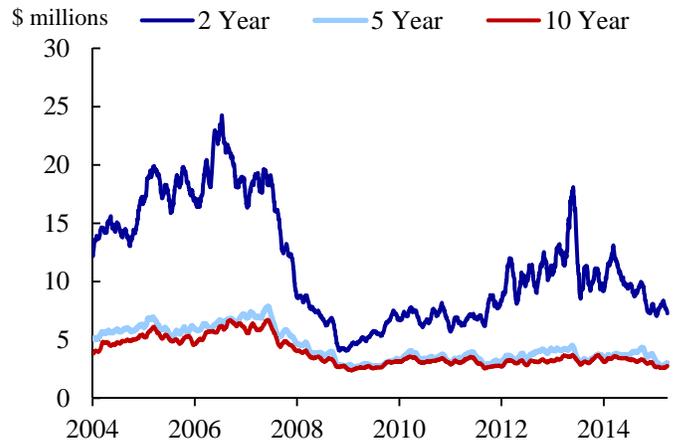


Figure 4.13: Benchmark Price Impact (Cash)



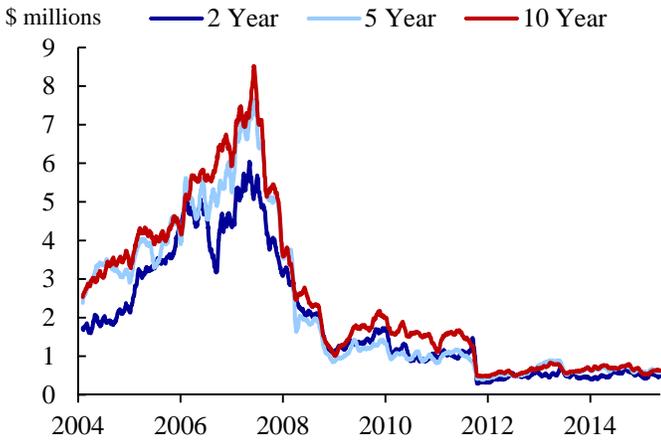
Note: Slope coefficients from weekly regressions of 5" price changes on 5" net order flow for the on-the-run notes
 Source: Staff calculations, based on data from BrokerTec.

Figure 4.14: Benchmark Trade Size (Cash)



Note: 21-day moving average; Average trade size; On-the-run notes
 Source: Staff calculations, based on data from BrokerTec.

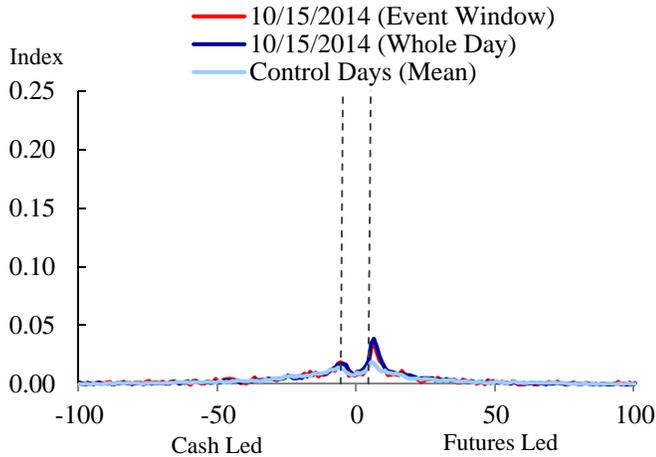
Figure 4.15: Treasury Active Contract Trade Size (Futures)



Note: 21-day moving average; 8:20 - 15:00 ET
 Source: Staff calculations, based on data from CME Group.

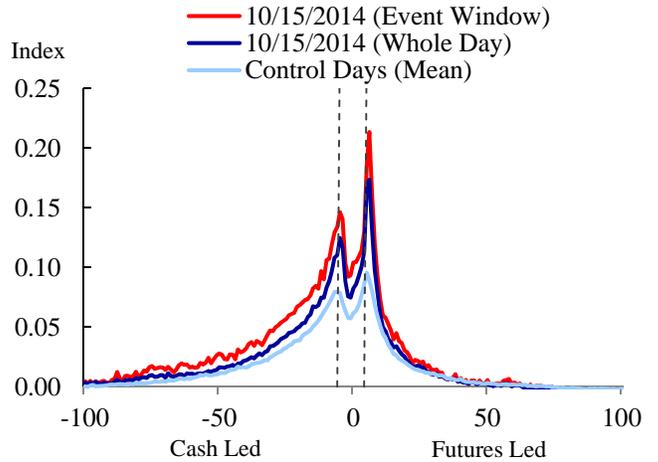
Appendix B Figures

Figure B.1: Top 10 Bank/Dealers: 10Y Cash vs 10Y Futures



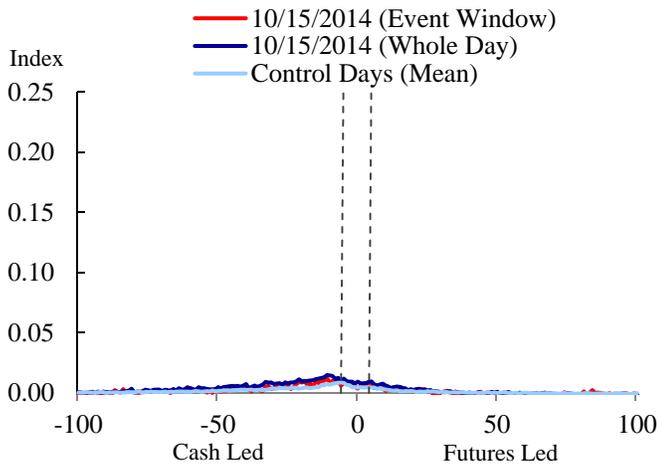
Note: Millisecond observations
Source: Staff calculations, based on data from BrokerTec, CME Group.

Figure B.2: Top 10 PTF: 10Y Cash vs 10Y Futures



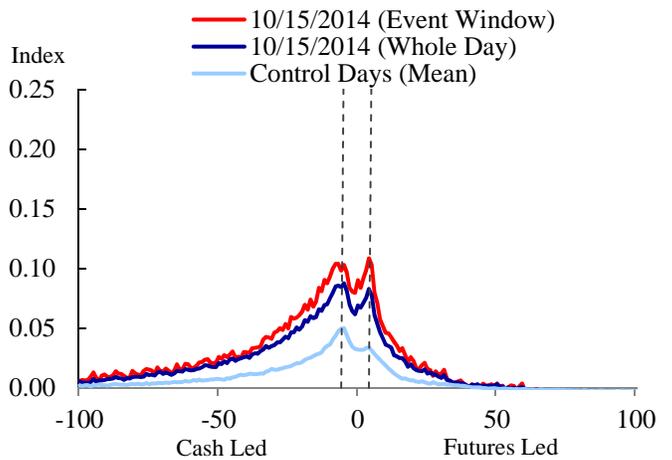
Note: Millisecond observations
Source: Staff calculations, based on data from BrokerTec, CME Group.

Figure B.3: Top 10 Bank/Dealers: 10Y Cash vs Eurodollar Futures



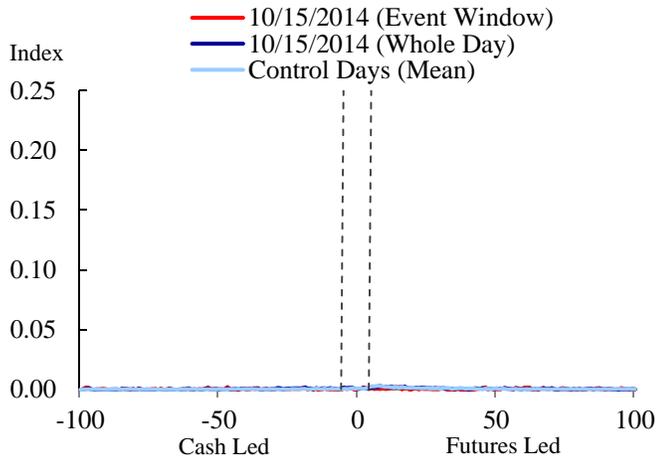
Note: Millisecond observations
Source: Staff calculations, based on data from BrokerTec, CME Group.

Figure B.4: Top 10 PTF: 10Y Cash vs Eurodollar Futures



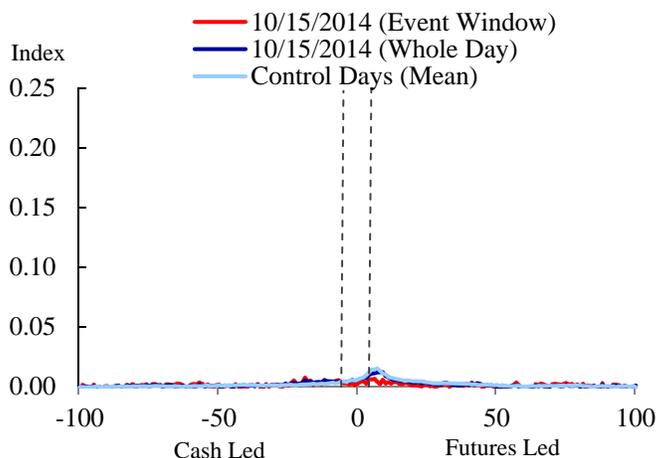
Note: Millisecond observations
Source: Staff calculations, based on data from BrokerTec, CME Group.

Figure B.5: Top 10 Bank/Dealers: 10Y Cash vs E-Mini Futures



Note: Millisecond observations
Source: Staff calculations, based on data from BrokerTec, CME Group.

Figure B.6: Top 10 PTF: 10Y Cash vs E-Mini Futures



Note: Millisecond observations
Source: Staff calculations, based on data from BrokerTec, CME Group.



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