The Liquidity Hierarchy in the U.S. Treasury Market:
Summary Statistics from CBOT Futures and TRACE Bond Data

by Lee Baker, Lihong McPhail, and Bruce Tuckman[1]

December 3, 2018

Introduction and Executive Summary

There is a great deal of interest in understanding the relative liquidity of futures contracts and cash securities in the U.S. Treasury market.[2] High-quality data on futures trading has existed for quite some time, but data availability on cash trading has recently been significantly enhanced. As of July, 2017, members of the Financial Industry Regulatory Authority (FINRA) have been required to report their transactions in Treasury securities through the Trade Reporting and Compliance Engine (TRACE).[3]

The purpose of this note is to combine this relatively new source of data on cash transactions with futures transactions data available at the CFTC to describe a "liquidity hierarchy" in the U.S. Treasury market. More specifically, the tables and figures presented here compare the volumes of risk traded across various cash securities (i.e., notes and bonds) and futures contracts.

The results of the analysis are the following:

- While overall risk volume is greater across all cash securities than across all futures contracts, the liquidity hierarchy is more complex, with certain futures contracts more liquid than certain cash securities, and *vice versa*;
- Futures contracts play a special role in liquidity-challenged environments. The relative amount of risk traded through futures contracts is higher on days with large price movements and is larger at times outside of U.S. trading hours.
- Average trade size, in risk terms, is much higher for cash securities than for futures contracts. This is most likely due to the higher prevalence of automated trading in futures markets, which, in turn, results in futures trades being broken down into smaller orders for execution.

Data and Methodology

This note combines transactions data in the cash securities market from TRACE with transactions data in the futures market at the CFTC. The data set starts with the TRACE reporting

---

[1] Office of the Chief Economist, Commodity Futures Trading Commission. While this paper was produced in the authors' official capacity, the views expressed here are those of the authors and do not necessarily reflect the views of other Commission staff, the Office of the Chief Economist, or the Commission. The authors thank Pat Fishe, Richard Haynes, Esen Onur, staff at the Office of the Chief Economist, and staff at the Department of the Treasury for helpful comments and suggestions. The authors particularly thank Dave Chung for invaluable guidance in understanding TRACE data.

[2] For similar summary statistics on the relative liquidity of Treasury futures and cash instruments, see, for example, CME Group (2016, 2018a, 2018b), Prudential Fixed Income (2016), and Younger, Iglesias, and Sarkan (2016). On the related question of price discovery in Treasury futures and cash markets, see, for example, Dobrev and Schaumburg (2017) and Mixon and Tuzun (2018). Joint Staff Report (2015) analyzes cash and futures liquidity in the context of the Treasury market events of October 15, 2014.

[3] TRACE data is shared with members of the Interagency Working Group on Treasury Market Surveillance (IAWG). The IAWG's goals are to enhance official-sector monitoring of the Treasury securities market; to improve the understanding and transparency of the market; to not adversely affect market functioning or liquidity; and to not unduly favor one group of participants in the market. Recent studies using TRACE data include Brain *et al.* (2018a, 2018b).

requirements on July 10, 2017, and continues through June 1, 2018, which amounts to 229 days of trading in both cash and futures. It should be noted that the data set does not contain the entirety of cash trades because only trades in which a FINRA member participates are reported to TRACE.

Bucketing of Cash Securities and Futures Contracts

Using risk-adjusted volumes, this note creates a liquidity hierarchy across mutually exclusive buckets of cash securities and futures contracts. These buckets have been defined here as follows:

Six Buckets of On-the-Run (OTR) Cash Securities

The U.S. Treasury conducts regular auctions of bonds at each maturity point.[4] An OTR bond is defined as the most-recently issued bond at a particular original maturity.[5] The 6 buckets correspond to the 2-, 3-, 5-, 7-, 10-, and 30-year maturity points.

Six Buckets of "Old" Cash Securities

When a new bond is issued, it becomes the new OTR of its maturity point. At the same time, the bond that had previously been OTR at that maturity point becomes the old bond. The 6 buckets for old bonds correspond to the same maturities as the OTR buckets.

"Double-old" Cash Securities

As just described, when a new bond is issued, the OTR bond is bumped down to become an old bond. Similarly, the old bond is bumped down to become a double-old bond. Trading volume attributed to this bucket is the sum of the trading volumes of all 6 double-old bonds in the bucket.

Cheapest-to-Deliver (CTD) Cash Securities

Every futures contract has a CTD, which, loosely speaking, is the bond most likely to be delivered in fulfillment of that contract's specifications.[6] The trading volume attributed to this bucket is the sum of the volumes of the 6 CTD bonds in the bucket,[7] where each CTD corresponds to one of the 6 futures contracts considered in this note (see below).

Other Cash Securities

This bucket contains all fixed-rate coupon notes and bonds that are not captured by the buckets listed so far. The trading volume attributed to this bucket is the sum of the trading volumes across these well over 300 individual securities.

Note that this bucket, and this study, does not consider TIPS (Treasury Inflation Protected Securities), floating-rate notes, and STRIPS (Separate Trading of Registered Interest and Principal of Securities), which are essentially zero-coupon bonds.

---

[4] Consistent with industry jargon, "bond" is often used in this paper to denote both Treasury notes and bonds.
[5] This study uses a time series created by FINRA to set the exact date on which a particular bond becomes OTR.
[6] For a detailed description of futures contracts and CTD bonds, see, for example, Tuckman and Serrat (2012), Chapter 14.
[7] On some days and for some contracts, the CTD is the old or double-old bond, in which case that bond's volume is added to the old or double-old bucket.

Six Buckets of Futures Contracts

The 6 buckets correspond to the following contracts, which are all listed on the CBOT (Chicago Board of Trade): 2-year T-Note; 5-year T-Note; 10-Year T-Note; Ultra 10-Year T-Note; T-Bond or 30-Year T-Bond; and Ultra T-Bond or Ultra 30-Year T-Bond.

Contracts expire in the months of March, June, September, and December, and almost all of the trading in each contract occurs in the front or near contract. During October 2018, for example, almost all of the trading occurs in the December 2018 contracts. As the expiration month approaches, however, traders "roll" their contracts into the next expiring contract. During November 2018, for example, traders exit their positions in the December 2018 contracts and establish positions in the March 2019 contracts.

For the purposes of this study, the volume in each contract is taken to be the sum of the volume of the 2 front contracts, but calendar spread trades—e.g., selling December 2018 and buying March 2019, or *vice versa*—are excluded. In other words, the volume in each contract is taken to be the volume of the 2 front contracts minus an approximation of roll activity.[8]

<u>Risk-Adjusted Volume</u>

The goal of this note is to present a liquidity hierarchy by comparing traded volume across the buckets of cash securities and futures contracts that were just described. To make the comparisons most meaningful, however, trade size is converted into a risk-equivalent amount, that is, into the amount of interest rate risk that is transferred by the trade.

Risk equivalents are most obviously useful to compare the trade of a face amount of bonds with the trade of a number of futures contracts. But risk equivalents are also desirable when comparing trades of two different bonds or of two different contracts. For example, a \$100,000 trade of a 30-year bond might, at first glance, seem equivalent to a \$100,000 trade of a 2-year bond, but the former trade represents more than 10 times as much interest rate risk transfer as the latter.[9]

More specifically, this note converts trade sizes to "dollar DV01" equivalents.

Consider, for example, a trade of \$200,000 face amount of 10-year bonds, when the DV01 of that bond is \$0.085.[10] The dollar DV01 equivalent trade size is \$200,000x.085/100, or \$170. Put another way, the size of that trade is such that, if interest rates move by 1 basis point, the value of the trade changes by \$170.

For the dollar DV01 equivalent of a futures contract, this note uses the DV01 of the CTD bond into that contract, adjusted for that bond's conversion factor.[11,12] Consider, for example, a trade of 5 10-

[8] Empirical analysis, not shown here, confirms that calendar spread trades are concentrated around the roll period.
[9] At a yield of 3%, the DV01 of a 30-year par bond is 0.197, while the DV01 of 2-year par bond is .019.
[10] The DV01 of a bond is the price change of \$100 face amount of that bond when its yield changes by 1 basis point. For a fuller explanation, see, for example, Tuckman and Serrat (2012), pp. 142-145.
[11] This is a simplification for two reasons. First, bonds that will actually be delivered may not be the CTD bonds because futures contracts have embedded delivery options. Over the sample period, however, the values of these delivery options were very small because interest rates were very low relative to the notional coupon of the futures contracts. Second, the DV01 of the futures contract is more closely approximated by the converted DV01 of a forward position in the CTD to the expiration date of

year futures contracts, where each contract requires the delivery of $100,000 face amount of bonds; the CTD has a DV01 of $0.06; and the conversion factor of the CTD is 0.8. Then the dollar DV01 equivalent of that trade is taken to be 5 x $100,000 x (.06/100) / 0.8, or $375.

Average % DV01 Volume

The main metric of the liquidity hierarchy in this note is "% DV01 Volume." All of the trades on a given day are converted into dollar DV01 equivalents. These equivalents are then dropped into the appropriate buckets and added together to give a dollar DV01 volume for each bucket on that day. The % DV01 volume for each bucket on that day is the dollar DV01 volume for the bucket divided by the sum of the dollar DV01 volumes across all buckets. Finally, the daily % DV01 volumes for each bucket are averaged across the days in the sample to give average % DV01 volumes.

Results

The Liquidity Hierarchy Across Futures Contracts and Cash Securities

In terms of risk volume, are futures contracts more or less liquid than cash securities? On average across the sample, across all instruments, futures contracts comprise 44% of total DV01 volume in the U.S. Treasury market compared with cash securities at 56%. But these overall numbers obscure a more complex instrument-by-instrument story.

Figure 1 shows the liquidity hierarchy of futures and cash instruments, i.e., the average % DV01 volume for each of the buckets described in the previous section. The volumes of futures contracts are depicted by red bars, of OTR bonds by blue bars with a black border, and of other cash securities by black bars. While not shown in the figure, the standard deviations of these percentages are quite small.[13]

The 10-year futures contract is the most liquid contract by a comfortable margin, at 19% of total DV01 volume. The 10- and 5-year OTR bonds are next, with 15% and 10%, respectively, followed by the 30-year futures contract and the 30-year OTR bond with 9.5% and 9.3%, respectively. The less liquid buckets similarly are a mix of futures and bonds. In short, for reasons likely relating both to history and market factors, neither futures nor cash dominate the liquidity landscape.

Figure 1 very much makes clear, however, that, outside of the OTR bonds, cash securities comprise small percentages of overall risk volume. Apart from the 30-year old bond, at 2%, none of the other buckets described above comprise even 1% of total DV01 volume. Put another way, futures contracts and OTR bonds comprise about 87% of total DV01 volume, while the remaining 13% is divided across the more than 300 remaining cash securities.

---

the contract. However, the relevant forward period is short, and at all times less than 6 months, because only the front two contracts of each maturity are used in this study. Furthermore, no data is available on how much of the volume of Treasury trades is executed with repurchase agreements, which would turn that cash volume into forward trades.

[12] For background on futures contracts, CTDs, and contract DV01s, see, for example, Tuckman and Serrat (2012), Chapter 14.

[13] For example, the 95% confidence interval around the 10-year futures contract mean DV01 volume of 18.7% is (18.3%, 19.1%).

Futures vs. Cash Volume in Liquidity-Challenged Environments

While individual futures contracts and cash securities clearly vie for positions in the liquidity hierarchy, futures play a particularly important role in liquidity-challenged environments. In particular, the average % DV01 volume of futures contracts rises relative to that of cash securities both when price volatility is high and during Asian and European trading hours.

For the purposes of this analysis, the price volatility on a given day is defined as the intra-day price range of the 10-year futures contract, i.e., the difference between the high and low trade prices of that contract on that day. Days are then categorized into four volatility groups: two high-volatility groups, namely, the 90th and 75th percentiles of volatility, and two low-volatility groups, namely, the 25th and 10th percentiles.

For the most part, the DV01 volume of individual futures contracts and cash securities increases with volatility. And the total DV01 volume across all instruments on high volatility—90th percentile—days is, on average, more than double the volume on low volatility—10th percentile—days. But the focus of this note is on relative volumes across instruments.

As reported above, DV01 volume across all days is distributed 44% in futures and 56% in cash. On high volatility days, however, futures comprise a larger percentage of DV01 volume: 47% and 49% in the 75th and 90th percentile of days, respectively. By contrast, on low volatility days, futures comprise a smaller percentage of volume: 43% and 42% in the 25th and 10th percentiles, respectively.

Behind these averages, however, is a more granular story about the migration of relative liquidity when volatility is particularly high or low. Figure 2 shows average % DV01 volume for various instrument buckets and groups of buckets for 4 sets of days. The red bars show results for the high volatility days, with the dark red bars showing the 90th percentile of volatility and the light red bars the 75th percentile. Similarly, the blue bars show results for low volatility days, with the light and dark blue bars showing results for the 25th and 10th percentiles, respectively.

Four futures contract groups are depicted on the left side of the figure. For each of these groups, futures comprise a higher percentage of DV01 volume on higher volatility days than on lower volatility days. The effect is particularly pronounced, however, for the most liquid bucket, namely, that 10-year futures contract. For that contract, average % DV01 volume is 21% and 20% on high volatility days, compared with 18% and 17% on low volatility days.

Four groups of cash securities are depicted on the right side of Figure 2. For the two most liquid groups, the 10- and 5-year OTR bonds, the average % DV01 volume is relatively flat across the volatility categories. For the 30-year OTR bond, % DV01 is a bit higher on low volatility days. Most striking, however, is the group "All Other Cash" securities, which includes all bonds other than the 10-year, 5-year, and 30-year OTR.[14] The % DV01 volume of this group is 18% or 19% in the high volatility days, but 23% or 24% on the low volatility days.

In very broad brushstrokes, as volatility increases, % DV01 volume migrates from relatively less liquid cash securities to relatively more liquid futures contracts.

[14] Note that this "All Other Cash" group is broader than the "Other Cash" bucket defined in the Data and Methodology section and appearing in Figure 1.

Futures also increase in relative importance in another liquidity-challenged context, that is, trading outside U.S. hours. Of total DV01 volume over the sample, 84% is traded during U.S. trading hours, 12% during European trading hours, and 4% during Asian trading hours.

Once again, across all instruments, futures comprise 44% of DV01 volume and cash 56%. During the much less liquid Asian and European trading hours, futures comprise 59% and 68% of DV01 volume, respectively. During the more liquid U.S. trading hours, futures comprise 43% of DV01 volume.

Figure 3 breaks down the trading hours results by instrument. In almost all cases, futures are a bigger fraction of risk transfer outside U.S. trading hours than during U.S. trading hours, while the reverse is true for cash securities.

The trading hour effects are particularly pronounced for the super-liquid 10-year futures contract and for all but the most liquid cash securities. The 10-year futures contract comprises 16% of risk volume during U.S. trading hours, but over 30% of volume outside those hours. By contrast, "All Other Cash" securities, defined just as in Figure 2, comprise 24% of risk volume during U.S. trading hours, but only 13% and 8% during Asian and European trading hours, respectively.

Given that the % DV01 volume of European trading hours is greater than that of Asian trading hours, one might have expected that the shift to futures and away from cash would have been greater in Asian trading hours than in European trading hours. But Figure 3 shows the opposite, a result for which this note offers no explanation.

Conclusions about relative liquidity across different trading hours are subject to the limitations of the TRACE data. To the extent that cash trades not reported to TRACE, namely, those without the participation of a FINRA member, are particularly important outside of U.S. trading hours, the results presented here could understate relative cash volumes.

There is an old trading maxim that, at stressful times, you buy and sell not what you want to buy or what you have to sell, but what you can buy or sell. The analysis here shows that in the liquidity-challenged environments of high volatility or relatively quiet trading hours, traders put on and take off more risk in futures and less in cash. By contrast, when liquidity is relatively plentiful, traders have the luxury of being particular with respect to the exact instruments through which to move risk.

Trade Size

The analysis presented to this point has illustrated that individual futures contracts and cash securities have particular places in the U.S. Treasury liquidity hierarchy and respond differently to the liquidity environment.

There is, however, one broad difference between risk trading in cash and futures: trade size is much greater for all OTR bonds than for futures contracts. For OTR bonds, the median and average trade size is $1,385 and $4,746 of DV01. The corresponding numbers for futures are much lower, at $180 and $499.[15,16]

[15] For readers less familiar with quoting trade size in terms of DV01, recall that the DV01 of a 10-year bond is about $.085 for 100 face amount. Therefore, for 10-year bonds, DV01 trade sizes of $1,385 and $4,746 would correspond to face amounts of $1,385/.085% or about $1.6 million, and $4,746/.085% or about $5.6 million, respectively.

Unlike the previous results in this note, Figure 4 shows that the large differences between OTR bond and future contract trade sizes hold across all individual instruments. It is also clear from Figure 4 that the distribution of trade sizes is skewed toward larger trades—in all cases the average trade size significantly exceeds the median.

A likely explanation for the difference in trade sizes is the difference in the microstructure of the two markets. About 80% of the futures trades in the sample are algorithmic. While cash markets have become more electronic over time, the extent of algorithmic trading and execution is much less in cash than in futures markets.[17] In other words, algorithmic trading, which tends to break overall trade demand into a sequence of many small orders, is much more prevalent in futures markets.

Conclusion

The recent availability of TRACE data on trading of cash securities presents an opportunity not only to study the U.S. cash Treasury market in isolation, but also to study the U.S. Treasury market complex, which includes futures contracts as well as cash securities.

Along these lines, this note uses % DV01 volume to show i) the complexity of the liquidity hierarchy with respect to individual segments of the cash and futures markets; ii) relative volume migrates from the least liquid cash securities to futures contracts in liquidity-stressed environments; and iii) trade size, in DV01 terms, is much larger for OTR cash securities than for futures contracts.

[16] Calendar spreads of futures contracts, which are omitted from this study, have higher average trade sizes than outright futures trades. But the average calendar spread trade is still significantly smaller than the average cash trade.
[17] See, for example, Brain *et al.* (2018) and McPartland (2018).

Figure 1. Average % DV01 Volume by Instrument, July 10, 2017 – June 1, 2018. The bars represent the average daily traded DV01 in each instrument bucket as a percent of the total DV01 traded.

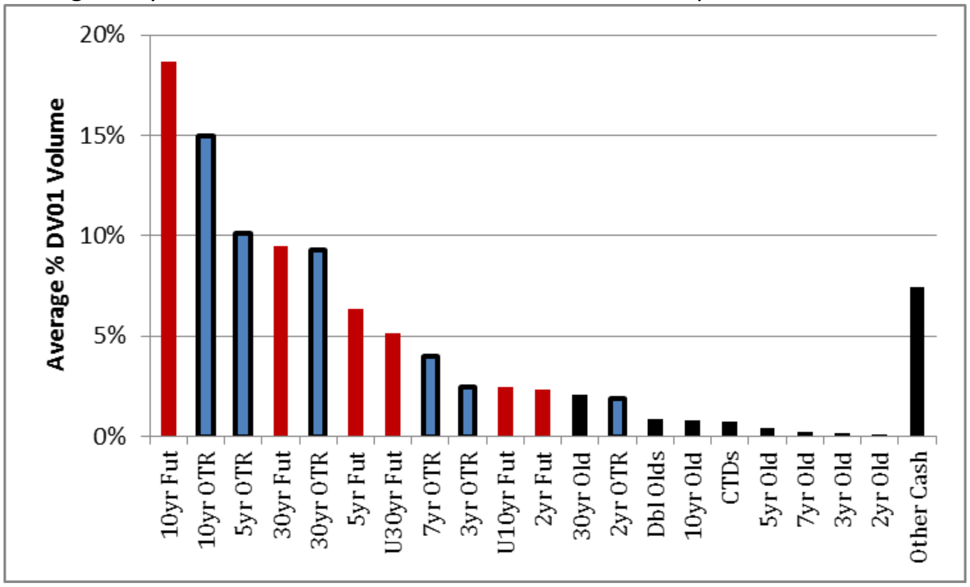


Figure 2. Average % DV01 Volume by Instrument and Volatility Percentiles, July 10, 2017 – June 1, 2018. The bars represent the average daily traded DV01 as a percent of total DV01 traded in each instrument bucket and each volatility percentile. Daily volatility is measured as the intra-day price range of the 10-year futures contract.

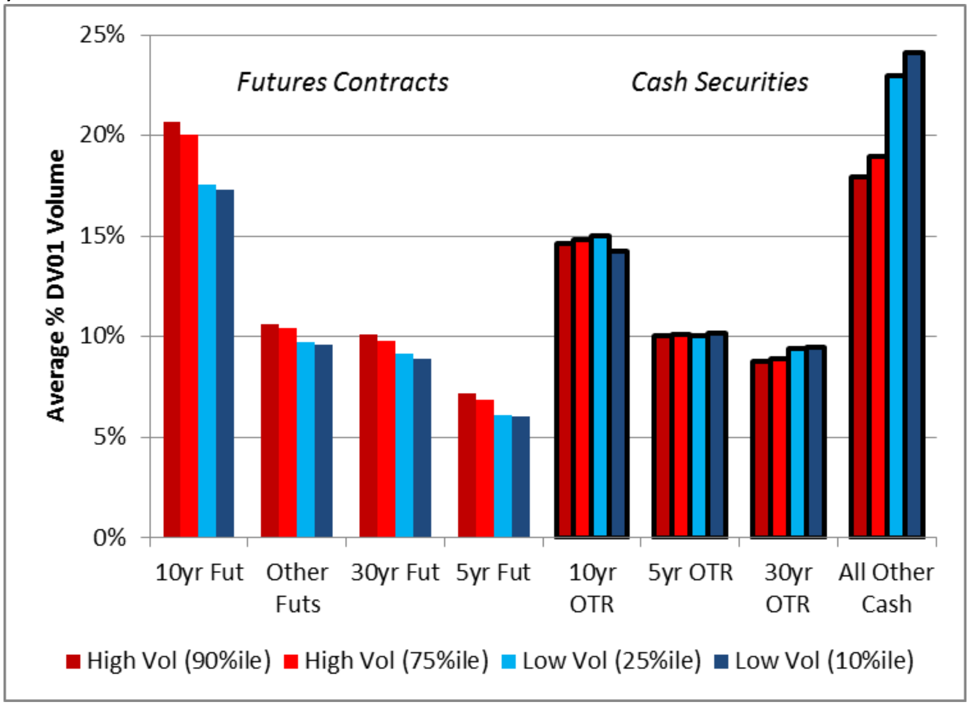


Figure 3. Average % DV01 Volume by Instrument and Trading Hours, July 10, 2017 – June 1, 2018. The bars represent the average daily traded DV01 as a percent of total DV01 traded in each instrument bucket and each of U.S., Asian, and European trading hours.

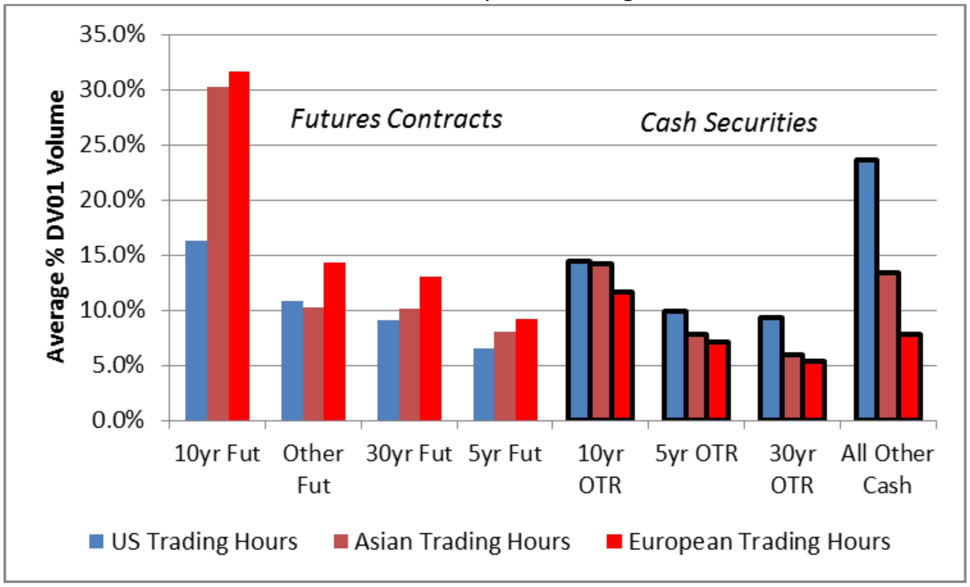
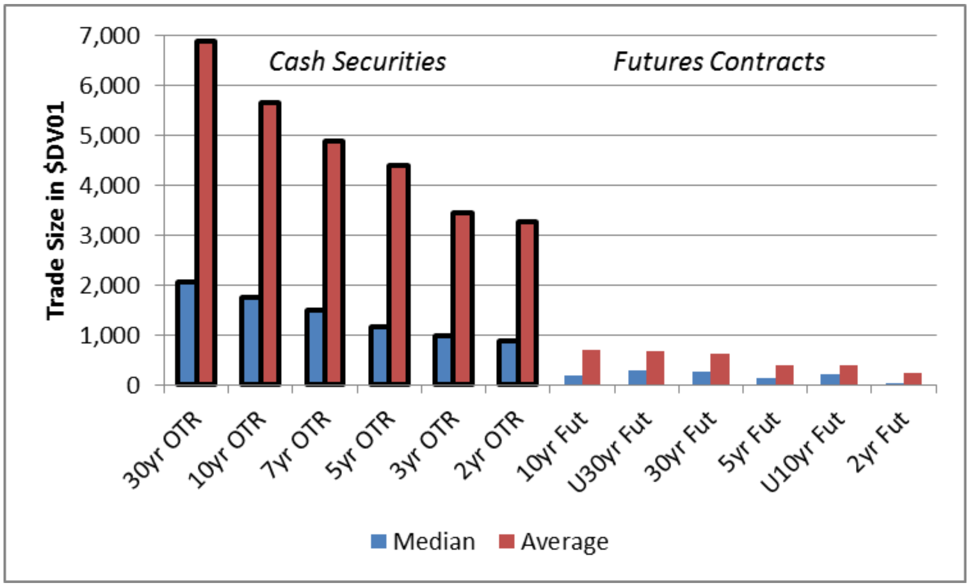


Figure 4. Average and Median Trade Size, quoted in Dollar DV01 by Instrument, July 10, 2017 – June 1, 2018.



References

Brain, D., De Pooter, M., Dobrev., D., Fleming, M., Johansson, P., Jones, C., Keane, F., Puglia, M., Reiderman, L., Rodrigues, T., and Shachar, O. (2018a), "Unlocking the Treasury Market through TRACE," FEDS Notes, Board of Governors of the Federal Reserve System, September 28.

Brain, D., De Pooter, M., Dobrev., D., Fleming, M., Johansson, P., Keane, F., Puglia, M., Rodrigues, T., and Shachar, O. (2018b), "Breaking Down TRACE Volumes Further," FEDS Notes, Board of Governors of the Federal Reserve System, Novermber 29.

CME Group (2016), "The New Treasury Market Paradigm: Treasury Futures," June.

CME Group (2018a), "Interest Rate Futures Liquidity Metrics Reach New Highs," Jan 5.

CME Group (2018b), "Interest Rate Futures Liquidity Update—H1 2018," July 17.

Dobrev, D., and Schaumburg, E. (2017), "High-Frequency Cross-Market Trading: Model Free Measurement and Applications," working paper, March 15.

Joint Staff Report (2015), "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, and U.S. Commodity Futures Trading Commission, July 13.

McPartland, K. (2018), "U.S. Treasurys Trade Electronically—But Where are the Algos?" Greenwich Associates, June 18.

Mixon, S., and Tuzun, T. (2018), "Price Pressure and Price Discovery in the Term Structure of Interest Rates," Finance and Economics Discussion Series 2018-065, Board of Governors of the Federal Reserve System.

Prudential Fixed Income (2016), "Request for Information," April. In response to "Notice Seeking Public Comment on the Evolution of the Treasury Market Structure," Federal Register 81(14), Department of the Treasury, January 22, 2016.

Tuckman, B., and Serrat, A. (2012), Fixed Income Securities: Tool's for Today's Markets, Third Edition, John Wiley & Sons.

Younger, J., Iglesias, A., and Sarkar, D. (2016), "24 hour party people redux: Global liquidity in U.S. Treasury Futures," J.P. Morgan, January 27.