Predictable End-of-Month Treasury Returns

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Abstract

We document a distinct pattern in the timing of excess returns on coupon Treasury securities. Average returns are positive and highly significant in the last few days of the month, and are not significantly different from zero at other times. A long Treasury position for just the last few days of each month gives a high annualized Sharpe ratio of around 1. We attribute this pattern to temporary spikes in investor demand for specific securities due to window dressing and portfolio rebalancing. We find evidence in quantities that aggregate insurer transactions contribute to the end-of-month price pattern. In particular life insurers are large net buyers of Treasury securities on benchmark index rebalancing dates.

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We document a distinct pattern in the timing of excess returns on coupon Treasury securities. Average returns are positive and highly significant in the last few days of the month, and are not significantly different from zero at other times. A long Treasury position for just the last few days of each month gives a high annualized Sharpe ratio of around 1. We attribute this pattern to temporary spikes in investor demand for specific securities due to window dressing and portfolio rebalancing. We find evidence in quantities that aggregate insurer transactions contribute to the end-of-month price pattern. In particular life insurers are large net buyers of Treasury securities on benchmark index rebalancing dates.

1. Introduction

U.S. Treasury securities comprise the largest asset market produced by a single issuer, the U.S. Treasury Department, with $16 trillion in marketable debt outstanding. Because of the market's depth and risk-free status, the yield curve across different maturities serves as a benchmark to price other fixed income instruments. Relative price differences among comparable Treasury securities tend to be small and short-lived. For these reasons, one might not expect to find a systematic opportunity to earn excess returns in the Treasury market. In this paper, we document a within-month pattern in longer-maturity Treasury security prices that produce large and significant unconditional average excess returns that increase with maturity, and we find a corresponding within month-pattern in net Treasury purchases by U.S. insurers, driven at least partly by a non-risk-based friction.

The excess Treasury returns that we document exploit a systematic richening of Treasury coupon securities in the last days of the month. In contrast, excess Treasury returns are not significantly different from zero at other times. Specifically, we estimate returns with a strategy of purchasing the Treasury coupon security in the days just before the end of the month, and then selling it on month end. The end-of-month effect is persistent over our sample period (1990 to 2018), the effect is pervasive across the universe of Treasury securities, and we find evidence of spillover in Treasury futures and interest rate swaps. The spillovers that we find are consistent with demand shocks for Treasuries having "local" effects on the prices of other close substitutes, as predicted theoretically in preferred habitat models, and documented in the recent empirical study of Gorodnichenko and Ray (2017).

This is not a risk free arbitrage opportunity – the return in any individual month may be negative. As compared to Treasury bills, Treasury coupon securities experience greater price risk because of their longer duration. Nonetheless, we find that the excess return from a selffinanced end-of-month long Treasury strategy gives an annualized Sharpe Ratio of around 1, after accounting for transactions costs. This is comparable to the risk-adjusted return for several other important anomalies (see, for example, Burnside, Eichenbaum and Rebelo (2011) and Lou, Yan and Zhang (2013)).

Calendar patterns in returns are often attributed to "window dressing." The idea is that firms or portfolio managers engage in window dressing in order to improve the profile of the firm's balance sheet or the manager's portfolio profile on the date(s) that this information is available to investors and/or regulators. Such phenomena have long been documented for equity securities (see, for example, Keim (1985) and Lakonishok, Shleifer, Thaler and Vishney (1991), Etula, Rinne, Suominen and Vaittinen (2019)) and for corporate bonds (Schneeweis and Woolridge (1979), Jordan and Jordan (1991) and Chang and Huang (1990). Post-crisis regulation has accentuated some patters in asset returns. Du, Tepper and Verdelhan (2018) document a failure of covered interest parity that is especially stark around month end. Munyan (2015) shows quarter-end patterns in the repo market driven by regulatory requirements of non-U.S. banks.

In the Treasury market, Kamstra, Kramer and Levi (2015) document a lower frequency pattern of relatively high monthly Treasury excess returns in the fall, as compared to the rest of the year, which they attribute to seasonally varying investor moods. Lou, Yan, and Zhang (2013) find positive excess returns after Treasury auction dates. Recent research has also documented relative return differences among comparable Treasury securities: Hartley and Jermann (2017) with floating rates notes since their issuance in 2014, relative to bills, and Musto, Nini and Schwarz (2018) with off-the-run bonds versus notes.

Our research is mostly closely related to the finding of seasonal patterns in the Treasury bill markets. Park and Reinganum, 1986 document anomalous pricing of Treasury bills that mature in the last week of the month. The authors test candidate explanations for the effect, but none are supported by the data. We find within-month unconditional average excess returns in a new place, Treasury coupon securities. The magnitude of this effect (e.g. excess returns of around 20 basis points per month at the 10-year maturity) accounts for the entire term premium in risk free rates and implies a Sharpe ratio of around 1. We also relate the price effect on Treasury coupon securities to quantities in the secondary market. To do this, we obtain CUSIP-level Treasury transactions of insurance companies at a daily frequency, which allows us to compute the average net purchases of insurers by proximity to the end-of-month date. Net month-end purchases of Treasuries by insurers in aggregate exceed net purchases on any other day of the month, suggesting that this investor class may contribute to the anomaly. Moreover, their net purchases are concentrated in the particular Treasury securities that are added to benchmark indices at the end of the month.

To isolate a potential demand shock associated with the securities' changing roles in the index, we compare the average net purchases of each security by different insurer types, on each day of the month. Insurers that benchmark their performance more closely to indices show relatively greater net purchases of the securities that are added to the index, and these purchases are disproportionately concentrated on the end-of-month rebalancing date. The index rebalancing effect is temporary, which suggests that the index demand shocks are not incorporated into the "fundamental" value of the relative asset prices. The results evidence a role for temporary but predictable demand shifts in explaining the end-of-month excess return anomaly. This contrasts with a risk-driven explanation of the intra-month pattern in average excess returns. Index-driven demand shocks may become more important to prices over time as a larger share of bond investments is allocated to passive funds that mechanically track index changes.

The plan for the remainder of this paper is as follows. In section 2, we measure the within month timing of coupon Treasury returns and consider the risk-return tradeoff. In Section 3, we consider potential drivers of within month excess returns. Section 4 examines the effects in on-the-run Treasuries, futures contracts, and interest rate swaps. Section 5 looks at flows of Treasury securities by U.S. insurers around the end of the month. Section 6 concludes.

2. Within Month Timing of Returns

2.1 Return Strategy

We first consider the returns on a strategy of buying a zero-coupon Treasury security t trading days before the end of the month, and selling it on the last day of the month (at the close of business). This position has to be financed, and we think of it as being financed at the general collateral (GC) repo rate. We therefore consider the excess returns as the Treasury return minus the GC repo rate. We use the smoothed zero-coupon yield curve of Gürkayanak, Sack and Wright (2007), which is fit to off-the-run Treasury coupon securities. The fact that this is an off-the-run yield curve in turn makes it legitimate to think of financing at the GC repo rate, rather than a specials repo rate. Though, financing at a specials rate, lower than the GC rate, would generate even higher returns.

For month m the excess return on a Treasury security over the last t trading days of the month is defined as:

$$xrm_m^L = \log\left(P_m^{N-\frac{C(t,m)}{365}}\left(E_m\right)\right) - \log\left(P_m^N\left(E_m - t\right)\right) - \frac{1}{360}\Sigma_{j=E_m-t}^{E_m-1} i_m\left(j\right) \tag{1}$$

where $P_m^N\left(j\right)$ denotes the price of a zero-coupon bond with a maturity of N years hence on the jth trading day of month m, E_m is the final trading day of month m, $C\left(t,m\right)$ is the number of calendar days between E_m and the day that is t trading days previous, and $i_m\left(j\right)$ is the overnight GC repo rate on the jth trading day of month m. The overnight repo contract is rolled over each day until the end of the month. An advantage to using the parameterization of Svensson (1994) is that we can construct the security prices of the exact maturities required ($N-\frac{C(t,m)}{365}$) with no approximation needed, apart from the fitting error of the yield curve. We consider holding positions from t trading days before the end of the month to the last trading day of the month. If there are weekends or holidays, the GC repo rate is scaled by the gap between trading days. For example, on a Friday, the GC repo rate would be multiplied by 3, assuming that the following Monday is not a holiday.

We compare the excess return over the last t trading days of the month to the excess return over all other days in the month, defined as:

$$xrm_m^{NL} = \log\left(P_m^{N-\frac{C^*(t,m)}{365}}\left(E_m - t\right)\right) - \log\left(P_{m-1}^N\left(E_{m-1}\right)\right) - \frac{1}{360}\left[i_m\left(E_{m-1}\right) + \Sigma_{j=1}^{E_m-t-1} i_m\left(j\right)\right] \tag{2}$$

where $C^*(t,m)$ is the number of calendar days between the last trading day of month $m-1$ and trading day $E_m - t$ in month m.

We consider data from January 1990 to the end of 2018. In Table 1, we report the unconditional average excess returns over the final t days of the month and over other days in the month, for different choices of the maturity N. The units are 100 times log returns, or approximate percentage points, per month (not annualized).

There are highly significantly positive excess returns to the strategy of investing in coupon Treasury securities over the last few days of the month. The excess returns are largest and most significant over the last 3 to 5 days of the month—not waiting until just the last day. For example, investing in the 10-year note over the last 3 days of the month gives an average excess return of 0.25 percent per month, which is 3 percentage points at an annualized rate. The magnitude increases with maturity, which is consistent with higher price risk for holding a longer duration security. Meanwhile, the average excess return over all other days in the month, shown in the lower panel of Table 1, is generally not significantly different from zero.[1] In this sense, the entirety of the term premium is earned at the end of the month.

2.2 Risk-Return Tradeoff

Of course, the average excess return is not the only important criterion; risk matters too. Figure 1 displays the excess return density for a long position in the 10-year note over the final two days of the month. The distribution peaks slightly above 0, and excess returns range from -2.10 to 3.03. This is not a case of "picking up pennies in front of a steam roller", whereby it is just a matter of time before an extreme negative return wipes out any prior earnings, unlike some strategies such as the carry trade where the risk premium can be thought of as compensation for jump risk. Indeed, the distribution is slightly positively skewed, which is consistent with a flight-to-quality response to negative shocks. It is useful to consider the sign of returns to the strategy during our sample. Table 2 shows that excess returns are positive around 55 to 70 percent of the time across maturities and distance from the month end.

Excess returns from our strategy are most often positive, but it is not a risk free opportunity. Still we should remember that the end-of-month trading strategy applies only for 12 short windows each year, limiting the risk. Table 3 compares the annualized Sharpe ratios from a long N-year security position over just the final t days of the month (upper panel) to that over all other days in the month (lower panel), for different choices of the maturity N. The Sharpe ratios from the end-of-month trading strategies are around 1 across

[1] The two-year yield is the exception. The average excess return is significantly positive, omitting the last day or the last two days of the month. However, the estimates are much less significant than the estimates on the final days of the month.

maturities. This is typical of the Sharpe ratios found in many finance "anomalies" (see, for example, Burnside, Eichenbaum, and Rebelo (2011) and Lou, Yan, and Zhang (2013)).

Accounting for risk has two distinct effects. First, the difference in price risk across maturities dampens the attractiveness of the trading strategy for longer maturity securities and increases its attractiveness at the short end of the curve. Although the 10-year yield gives a higher average excess return, it naturally exposes the investor to more duration risk. The best risk-reward tradeoff from the end-of-month strategy appears to be found for the 2- and 5-year maturities. Second, the higher risk to a longer holding horizon shifts the optimal timing of the strategy closer to the end of the month. The strategy is optimally implemented over the final 2 to 3 days of the month, over which there is less price risk, in contrast to the final 5 days of the month when considering excess returns alone. Holding horizon risk also explains the relatively unattractive Sharpe ratios from a strategy of holding a long Treasury position over all except the final t days of the month, which is now unambiguously less attractive than a long position over only the final few days of the month.

Transactions costs are important to consider when evaluating the attractiveness of any trading strategy. In our case, the holding period is only a few days and so the round-trip transaction costs are rapidly accrued. However, the typical off-the-run bid-ask spread is only 2 to 3 basis points (Musto, Nini, Schwarz, 2018). This is an order of magnitude lower than the average excess returns for the end-of-month trading strategy at the 10-year maturity. So transactions costs will barely make a dent in these excess returns. For shorter-maturity yields, the tradeoff between excess returns and transactions costs is more finely balanced.

2.3 Time Series Stability

One might wonder whether the pattern in Treasury excess returns has changed over time. There are only 12 observations per annum on the trading strategy, so it is difficult to assess structural stability. To summarize the evolution over time, we compute the average excess return on holding a zero coupon note for the last t days of the month, for five-year windows over our sample period, separately for each maturity. Table 4 shows that the estimates across maturities are positive in every single window, and significantly so in most. Five-year estimates are highest in the early 2000s, and smallest in the very first period of the sample, from 1990-1994, a time when the Treasury market underwent some technological advancements, such as electronic automation of Treasury auctions.

The estimates in the final period, from 2015-2018 are smaller than most of the other periods, but they remain significant. This raises the possibility that the pattern will be weaker now that regulators have given more attention to the unintended consequences of balance sheet regulation that uses month-end or quarter-end snapshots. In order to formally test for structural breaks in the excess returns, we conduct a Bai-Perron (1999) sup-F test (where the break dates are not specified *ex-ante*). Allowing for up to 4 break dates, the p-value is greater than 0.25 at all maturity-break date combinations, far from being statistically significant. So we conclude that there is no real evidence of changing month-end patterns of excess returns, at least not with the sample available to us.

3. Potential Drivers

We now explore some potential drivers of the end-of-month excess returns that we find. Our trading strategy shows an attractive risk-reward profile, comparable to other well-known asset pricing anomalies. But, there is not an obvious macro-finance risk based explanation for the excess returns that we find. The return distribution over our sample (Figure 1) suggests that the end-of-month excess returns are not compensation for crash or disaster risk. Macroeconomic news announcements concentrated at the start and middle of the month, rather than at the end of the month. Further, Faust and Wright (2018) find that the unconditional excess returns on long bonds are not statistically significant around macroeconomic news announcements, although the time-varying risk premium is earned at these times. It is also difficult to impossible to explain the return anomaly with asymmetric information, as there is no private information to be had in Treasury securities. Some potential institutional explanations are the timing of Treasury auctions, balance sheet related window dressing, or flows into benchmarks that roll at the end of the month.

3.1 Auction Cycle

In order to investigate potential drivers of the anomaly, we view the within-month excess return pattern from a different angle. We compute the average excess returns from holding the Treasury security on the j-to-last trading day of the month. The last trading day of the month is 1, and so the average excess return for $j=1$ is equal to the average excess return for $t=1$ in equation (1). Figure 2 plots the average daily excess returns for trading days $j=1...19$. This presentation underscores the large and significant excess return on the final day of the month, across maturities. There are also smaller, but statistically significant returns on the second to last day of month and around the middle of the month.

Treasury auctions typically take place around the middle and the end of the month, and so this is a natural candidate explanation for the return pattern. Figure 3 plots the distribution of note auction dates since 1990, by days of the month. The auction distribution over our sample period is bimodal, peaking around the 10^{th} and 23^{rd} of the month. Lou, Yan and Zhang (2013) show that auctions affect fixed income yields, not just on the auction date itself, but in the days around the auction. On average, excess returns are negative in the days leading up to an auction and positive afterwards.

To explore how auctions relate to within month excess returns, we consider the effect of the auction day itself, as well as a window of days around each auction. Specifically, we regress the daily excess returns at each Treasury maturity point on indicator variables for the number of days before the last trading day of the month, augmented with 7 indicator variables for each auction---one indicator for the auction day itself, one for each of the 3 previous days, and one for each of the 3 subsequent days. We plot the coefficients on the day-to-end of month indicator variables in Figure 4. This is the analog of Figure 2, except now controlling for auctions. Excess returns do indeed tend to be depressed on the days before auctions, and boosted on the days after auctions, in line with Lou, Yan and Zhang (2013).

However, the same qualitative patterns can be seen in Figure 4 as were shown in Figure 2. Notably, the excess returns are still highest for the last trading day of the month and they remain highly significant. That controlling for auctions does not have a big effect on the estimates may not be that surprising because these excess returns are formed from off-the-run security prices, not those of the most recently issued securities. In section 4 we examine the returns for on-the-run securities. Our results show that that the auction is a significant, but distinct effect from the off-the-run month-end patterns that we document.

3.2 Balance Sheet Reporting

The asset pricing effect of balance sheet improvement around reporting dates is often referred to as window dressing. Window dressing could be driven by reporting to regulators or investors. For example, in the repo market, Egelhof, Martin, and Zinsmeister (2017) and Munyan (2013) describe quarter-end effects driven by the focus of some regulators on quarter-end balance sheet snapshots, while Lakonishok, Shleifer, Thaler and Vishney (1991) find that quarter-end effects in equities are driven by the performance-based motives of fund managers on dates that holdings are revealed to investors. The timing of window dressing effects can differ by market. Jordan and Jordan (1991) find that end-of-year and January effects are particularly strong in corporate bonds returns.

We ask which months of the year earn the premium in Treasury coupon securities, first examining quarter-end dates. Table 4 compares the average excess return over all month ends (top panel), on the j-to-last day of the month, to returns averaged over quarter-ends (bottom panel). The quarter-end specification weakens the significance and reduces the size of the estimates on the final day of the month for the 5- and 10-year maturities, and it is unchanged for the 2-year maturity. For longer maturity Treasury securities, the excess returns earned on the final day of the month are clearly not driven by a quarter-end phenomenon.

Now to consider each month individually, we report the average excess return on the j-to-last day of the month for a zero-coupon Treasury security, separately for each month, in the top panel of Table 5. The last day of the month alone shows positive average excess returns for every single month at all maturities. This is consistent with a systematically special role for the final day of the month. However, the size and significance of the sample estimates shows a less clear pattern across months. Averaged over maturities, the estimates are highest for January, July, October and November, but there is no single month for which the estimates are significant at the 1 percent level across all maturities.

The monthly average estimates alone do not paint a clear pattern in excess Treasury returns, and so we test the significance jointly across months. We first test the hypothesis that the average excess returns are the same for all months. The bottom panel of Table 5 shows p-values for the estimates on each of the last five days of the month, across maturities, which range from 0.31 to 0.89. It is not possible to differentiate excess returns among the individual months for any of the last five days of the month. Finally, we test the hypothesis that the average excess returns for all months are the same and are equal to zero. For the final day of the month alone, we decisively reject this hypothesis at the 5- and 10-year maturity, with p-values of 0.00 and 0.01, respectively. The 2-year maturity is less definitive, with a p-value of 0.13. But, the p-values for days other than the final day of the month range from 0.31 to 0.85, which does not allow us to rule out the possibility that excess returns on days of the other than the final day of the month are equal to zero. For longer maturity Treasury securities, we conclude the month end premium is earned on the final day of the month for *all* months, and that they earn the *same* premium on the last day of the month. Thus, if there is a window dressing effect for long maturity Treasury securities, it is driven by within month balance sheet adjustment, rather than a lower frequency.

As discussed in subsection 1.2, excess returns in the Treasury market increase with maturity. Results at the 2-year maturity are more difficult to identify because the excess return is relatively small in comparison to the longer horizon securities. Nonetheless, anomalous pricing of Treasury bills, the shortest-maturity Treasury securities, around the end of the month is a long-standing finding (Park, Yong and Reingaunum (1986)).

Our analysis is focused on Treasury coupon securities, but we could similarly implement the end-of-month trading strategy with Treasury bills. This entails financing a long Treasury bill position in the repo market over the last few days of the month. The narrow spread between repo and Treasury bill rates limits the potential profit to this strategy in this segment of the Treasury yield curve. For example, over our sample period from 1990 to 2018, the average excess return on 3-month bills is less than 1 basis point. As shown in section 1, the end-of-month excess returns on the 10-year note are around 25 basis points per month, which is more than an order of magnitude larger than any money market end-of-month effects. The annualized Treasury bill – repo rate spread would have to be about 5 percentage points (a level that it has never reached) to give the same expected profitability as shown for the 10-year note.

To summarize, if there is a window dressing effect in the Treasury market, it is driven by within month balance sheet adjustment, rather than at a lower frequency. Longer maturity Treasury securities allow for more profitable exploitation of window dressing exploitation than short-maturity Treasury securities, especially at the very shortest maturities in the bill market.

4. Tradeable Securities

The results so far have all been based on a smoothed yield curve fitted to smoothed off-the-run coupon securities. But in practice, any investor seeking to exploit this anomaly would have to use actual assets. In this section, we first estimate within month average excess returns with the universe of coupon Treasury securities outstanding. Then, we apply the strategy to Treasury futures contracts, and see whether the effect holds for rates outside of the Treasury market.

4.1 On-the-Run Estimates

One important way in which the estimation of excess returns differs for actual Treasury securities as compared to using a smoothed zero coupon curve, is that the universe of Treasury securities allows us to form excess returns for on-the-run Treasury securities, which are not included in the zero curve estimation. The greater frequency of trading and lower transactions costs for on-the-run securities make them a natural choice to implement a trading strategy to exploit the excess return pattern.

We form daily on-the-run returns with the price of the most recently issued security at each maturity point, omitting the auction dates. On-the-run securities would likely be financed as the specials repo rate corresponding to the particular security that would serve as collateral, in contrast to the GC repo rate. Specials repo data are difficult to obtain because there is no centralized trading platform. To form our on-the-run excess returns, we use the fact that a specials repo rate is bound above by the GC repo rate since specials collateral is a subset of the most highly demanded GC repo-eligible collateral. Thus, the assumption that the strategy is funded at the GC repo rate gives a conservative estimate of excess returns for on-the-run Treasury securities.

Treasury auction dates are most closely tied to the security that was just auctioned. In order to control for this, we compute the average excess returns from holding the Treasury security on the j-to-last trading day of the month as in section 3, by regressing the daily excess returns at each Treasury maturity point on indicator variables for the number of days before the last trading day of the month, augmented with 7 indicator variables for each auction---one indicator for the auction day itself, one for each of the 3 previous days, and one for each of the 3 subsequent days.

The top panel of Table 7 reports the coefficients on the day-to-end of month indicator variables, and the bottom panel reports the corresponding Sharpe ratios. The Sharpe ratios are formed using the point estimates from the upper panel. When comparing the on-the-run estimates to the off-the-run estimates (top panel of Table 5), it is important to recall that the duration is shorter than the time to maturity for the individual securities used in the on-the-run estimation. Over our sample, the average duration for the 2-, 5-, 10- and 3-year on-the-run securities is equal to 1.9, 4.5, 8.0, and 15.8 years, respectively. The on- and off-the-run estimates of daily within month excess returns are very similar; significant on the final day of the month and the second-to-last day of the month, with the size of the estimate increasing as the maturity lengthens and largest on the last day of the month. Adding up the estimates over the final two days of the month gives the trading strategy return for holding the security over the last two days of the month (*t*=2), in excess of auction-related effects. At the 30-year maturity, the two-day position produces an average 4.5 percent annualized excess return. The Sharpe ratios for the excess returns on the last day of the month are close to 1, also similar to those estimated for off-the-run securities. These results confirm that the end-of-month effect is as robust in on-the-run Treasury securities as it is in the rest of the market.

4.2 Futures and Swaps

Another venue to exploit the end-of-month effect in practice is the Treasury futures market. An advantage to taking a position in futures is that there is virtually no funding cost. Also, the contracts are heavily traded and so transactions costs tend to be even lower than in the cash Treasury market. The upper panel of Table 8 reports the average excess returns on 5-, 10- and 30-year Treasury futures contracts. Note that the delivery baskets for these contracts are all for maturities that are shorter than the headline maturity of the futures contract (e.g. the 10-year futures delivery basket is from 6.5 to 10 years) and the specifications of the contract coupled with the actual level of rates means that the cheapest to deliver is bound to be at the short end of this range. So a 10-year futures contract has a duration of about 6 years.

The average excess returns reported in Table 8 are highly economically and statistically significant. Annualized returns on the longest maturity futures contracts, held only over the last few days of the month, can exceed 3 percentage points.

Finally, we explore benchmark interest rates beyond Treasury securities, to see whether these effects show up elsewhere. The answer is that they do. We consider changes in swap rates from t days before the last day of the month until the last day of the month, again over the same sample period. The average changes in swap yields are shown in the lower panel of

Table 8, in basis points. They are negative and significant. Of course it is to be expected that they are negative, because here we are looking at yield changes, not returns.

5. End of Month Flows

In this section we complement our analysis of prices with data on quantities in the Treasury market. We obtain a unique dataset of CUSIP-level Treasury security transaction data- at the daily frequency. In the over-the-counter Treasury market disaggregated Treasury flow data are not easy to come by. And, of course, there cannot be any within-month pattern in aggregate Treasury flows (assuming that there is no such pattern in total Treasuries outstanding). So, our data give us the unique opportunity to examine the within-month pattern in Treasury flows for a subset of the market.

Our daily flow data are for U.S. insurers, an investor class that might have particular intra-month flows owing to window dressing or portfolio rebalancing motives. Collectively, insurers hold about three percent of the stock of U.S. Treasuries,[2] so they are not the largest aggregate clientele for these securities, but by the nature of their business insurers are an important source of demand for long maturity fixed income securities. Koijen and Yogo (2016) discuss effects of regulatory pressures on life insurers. U.S. insurers of all types are primarily regulated at the state level, but the National Association of Insurance Commissioners (NAIC) works to coordinate state policies. Statutory requirements vary by type of insurer and by regulatory authority, but one common risk-management principle is asset-liability duration matching, which could affect demand for long-maturity Treasury securities. Our dataset is the universe of transactions in Treasury securities by all U.S.-registered insurance

[2] The Federal Reserve's Financial Accounts data, Table L.209, shows the combined holdings of Life Insurers and Property and Casualty Insurers, as of 12/31/2008, to be $171 billion, compared with the $6.1 trillion of publicly held Treasury securities (other than savings bonds) then outstanding (see http://www.federalreserve.gov/releases/z1/current/ z1r-4.pdf).

companies, from 1990 to 2016. These data are based on Schedule D statutory regulatory filings collected by Mergent FISD.

5.1 Insurer Net Purchases

The average total net purchases of Treasuries by insurers broken out by the number of days until the last trading day of the month is plotted in Figure 5. The units are millions of dollars par value of securities. A striking run up in net purchases is apparent on the last few days of the month. Importantly, the timing of insurer purchases in the figure corresponds to the return earned on that security as calculated by the price change from the previous day. For example, a security purchase on the final day of the month corresponds to the change in price for that security from the second to last to the final day of the month. With this in mind, the figure shows that insurers are net buyers of Treasury securities precisely at the time that the price is highest. This is consistent with the finding by Musto, Nini and Schwarz (2018) that in aggregate, insurers tend to buy Treasury securities when they are relatively expensive and sell then when they are relatively cheap. It also suggests that insurers might be an investor class that is driving at least some of the systematic late-in-the-month rally in longer-maturity Treasury securities.

To the extent that we think that window dressing may be driving inflows at the end of the month, we should expect corresponding outflows early in the month. That is indeed the case in Figure 5. Although it is a little more spread out in time, the early half of the month is characterized by net Treasury outflows. Indeed, the quantity of net purchases on the final day of the month alone exceeds the sum of net purchases over all other days of the month.

Figure 6 shows the average total net purchases of Treasuries by insurers broken out by the number of trading days to the end of the month by the main policy focus of the insurer (life insurance, property and casualty, and health). Treasury inflows at the end of the month exist in all the insurer types, though they are dominated by the life and property and casualty insurers. This is not surprising since these two insurer types are the largest segments as measured by total asset size.

Is there a particular security profile in which insurers concentrate their purchases? Figure 7 shows the breakout of net purchases by days to the end of the month, for four different duration buckets (less than 2 years, 2-5 years, 5-10 years and more than 10 years). The inflows to Treasuries at the end of the month are largest in the 2- to 10-year maturity range, which is consistent with an effort to lengthen asset liabilities at the end of the month.

Using German life insurer data, Domanski, Shin and Shushko (2017) find evidence that demand for long-maturity assets to match long-horizon liabilities may generate a feedback effect on yields. Demand for long-maturity securities pressures long-term yields lower, thus heightening insurers' asset-liability duration mismatch due to negative convexity, which in turn further increases demand to buy the long-horizon securities. It is conceivable that insurer demand for long duration assets on the final days of the month may be partly in response to relatively higher long maturity prices (and thus returns) at the end of the month that increase their need to extend duration to match some benchmark, which in turn magnifies the end-of-month return boost to long-maturity securities.

5.2 Portfolio Rebalancing

Insurance firms display a clear pattern of buying at the end of the month, and selling early in the next month. But they may also be rebalancing within their Treasury portfolio around the end of the month. Risk-based capital charges are identical for all Treasury securities. So, a within-Treasury effect cannot be easily explained by window dressing. However, rebalancing within a specific asset class could be motivated by changes in the composition of the benchmark index. The asset allocation of insurers is typically guided by an internally customized benchmark that aims to capture the distribution of liability risks. Custom benchmarks are formed by combining broad benchmark indices. Given the sensitivity of policy holders' behavior and policy payouts to interest rates, a broad fixed income benchmark index is typically included as a component of the internal benchmark.

In order to tease out the insurers' Treasury security selection that may be attributable to within-Treasury rebalancing, we consider the particular securities that are added or dropped from a broad government bond index around the month-end. Specifically, we obtain the constituents of the Bloomberg Barclays' U.S. Treasury Index (LUATTRUU) over our sample period. We parse the insurer transactions into CUSIP-date pairs, and aggregate them into three groups; (1) CUSIP-date transactions that correspond to additions to the index, (2) CUSIP-date transactions that correspond to deletions from the index, and (3) all other CUSIP-date transactions. The Barclays Index is rebalanced on the final trading day of each month. So, we are most interested in the relative behavior among these three groups on the final day of the month.

On rebalancing dates, three securities are added to the index, on average, over our sample period, and three securities are dropped from the index. These added/dropped securities are a subset of the 348 nominal Treasury coupon securities that are outstanding, on average, on the month-end rebalancing dates. Less than 1 percent of coupon Treasury securities outstanding are being added to the benchmark index on month-end dates. As shown in the right panel of Figure 6, on average over the last day of the month, the par value of insurer net purchases of the three securities added to the index is greater than the total par value of all the securities that are neither added to nor dropped from the index. Insurer net purchases of the securities dropped from the index are negative, but small. These securities are sold by the insurers, but in a more gradual manner.

To investigate the propensity for index matching by insurer type, we break out the transactions into three subgroups that correspond to the three insurer types in Figure 6. The data show that, on average, life insurers' appetite for the few securities added to the index is almost double that of their net purchases of all other securities on month end dates. Property and Health insurers show the opposite in security selection. Their net purchases of index additions is a fraction of their net purchases outside of index additions on the last day of the month. This is closer to the proportion represented by the security population, but new index constituents are still overweight as a share of P&C and Health insurers' net purchases.

We take the subset of transactions for life insurers alone, and break out the net purchases of index additions by duration bucket. Net life insurer purchases of index additions are almost exclusively concentrated in securities with that have a duration greater than 5 years. Net purchases of index additions with less than 5 years duration comprise only 4 percent of the total index addition purchases for life insurers. This shows that life insurers in aggregate are buying the index additions as they become most expensive right on the rebalancing date.

However, the relatively rich purchase price may be partly offset by the insurers' use of the securities. First, indices tend to add the most recently issued securities on rebalancing dates, and so the insurer is buying mostly on-the-run securities to match index rebalancing. Transactions costs for on-the-run securities are low relative to less liquid securities that are further off the run. Though as noted in subsection 2.1, the savings will be small. Second, securities lending income can also be a valuable revenue source for institutions that hold large securities portfolios, such as insurers, and the most in-demand Treasury securities are typically those that have been most recently issued. Third, benchmark indices tend to give the highest weights to the most recently added securities, giving the insurers more "bang for their buck" in approximating the index returns. Finally, it is also worthwhile to keep in mind the motivation for benchmarking to a broad fixed income index – helping insurers to match the risk profile of liabilities with comparable assets. The fact that this end-of-month return effect is also present in Treasury futures returns and interest rate swaps is evidence that these risks can be managed in ways that may be more cost effective than outright Treasury security purchases. However, the treatment of any non-Treasury instrument will be more restricted in a regulatory sense.

6. Conclusion

We have documented a distinct pattern in the within-month timing of unconditional excess returns on coupon Treasury securities. Average returns are positive and highly significant in the last few days of the month, and are generally not significantly different from zero at other times. The entire term premium is concentrated in the last few days of the month.

A strategy of taking a long coupon Treasury security position over just the last few days of each month gives a high annualized Sharpe ratio of around 1. The most plausible drivers of this pattern are window dressing or portfolio rebalancing. It is striking however that it appears to affect the entire configuration of benchmark fixed income rates: Treasury securities, Treasury futures and interest rate swaps.

Looking at quantities, flow data indicates that insurers tend to be significant net buyers of Treasuries in the last few days of the month, especially the on-the-run securities. The aggregate pattern of insurer purchases may magnify the end-of-month return effect that we document, especially for long-maturity securities and those that have been most recently issued. Life insurers' particular appetite for the most recently added index constituents gives evidence of a demand-driven end-of-month effect for this subset of the Treasury market, separate from any risk-based explanation.

Most attention on month-end returns has been in money market instruments. Yet the trading strategies available at longer durations are more profitable, and the term structure of month-end effects has not been examined until now, as far as we know. For investors, the end of the month Treasury effect offers a profitable trading strategy. For regulators, the implications potentially span balance sheet regulation and auction policy. The results are an indication of the cost of balance sheet regulation to the financial system. Since end-of-month richening in Treasury securities is systematic over many years, there may be scope for the Federal government to shift issuance across maturities toward the month end in order to achieve lower coupon rates at auction.

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Table 1.
Cumulative Excess Returns

Maturity	Last t days, t = 1	2	3	4	5	6	7	8	9	10
2-Year	**0.03*** **	**0.05*** **	**0.06*** **	**0.06*** **	**0.06*** **	**0.06*** **	**0.05*** **	**0.05*** **	**0.05*** **	**0.06*** **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
5-Year	**0.09*** **	**0.13*** **	**0.15*** **	**0.15*** **	**0.17*** **	**0.15*** **	**0.13*** **	**0.12*** **	**0.10** **	**0.13*** **
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
10-Year	**0.14*** **	**0.20*** **	**0.25*** **	**0.24*** **	**0.28*** **	**0.26*** **	**0.23*** **	**0.23*** **	**0.21** **	**0.30*** **
	(0.03)	(0.04)	(0.05)	(0.06)	(0.06)	(0.07)	(0.07)	(0.08)	(0.08)	(0.09)
Maturity	All except last t days, t = 1	2	3	4	5	6	7	8	9	10
2-Year	**0.07*** **	**0.06** **	**0.05* **	**0.05** **	**0.04* **	**0.05** **	**0.05** **	**0.05** **	**0.05*** **	**0.04** **
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
5-Year	**0.13* **	**0.09**	**0.06**	**0.06**	**0.05**	**0.07**	**0.09**	**0.09**	**0.10* **	**0.07**
	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)
10-Year	**0.19**	**0.13**	**0.07**	**0.10**	**0.06**	**0.07**	**0.11**	**0.10**	**0.10**	**0.02**
	(0.14)	(0.13)	(0.13)	(0.13)	(0.12)	(0.12)	(0.11)	(0.11)	(0.11)	(0.10)

Notes: This table reports 100 times the average excess returns from equations (1) and (2), for different choices of t and N (the maturity of the Treasury security, in years). The top panel shows cumulative average excess returns over the last t days of the month. The bottom panel shows cumulative average excess returns over all days in the month except the last t days. The units are (approximate) percentage points per month (not annualized). The sample period is from 1990 to 2018. Standard errors are shown in brackets.

Table 2.
Percent of Excess Returns > 0

Maturity	Last t days, t = 1	2	3	4	5	6	7	8	9	10
2-Year	**63**	**67**	**68**	**67**	**64**	**62**	**59**	**60**	**57**	**57**
5-Year	**63**	**63**	**64**	**61**	**64**	**59**	**58**	**59**	**57**	**58**
10-Year	**61**	**61**	**65**	**59**	**61**	**59**	**59**	**59**	**55**	**58**

Notes: This table reports the percent of days over the sample period on which excess returns exceeded 0, for a holding period over the last t trading days of each month. The 2-, 5-, and 10-year maturities are shown. The sample period is from 1990 to 2018.

Table 3.
Annualized Sharpe Ratio

Maturity	t =	1	2	3	4	5	6	7	8	9	10
	Last t days										
2-Year		**0.97**	**1.11**	**1.10**	**0.95**	**1.00**	**0.79**	**0.70**	**0.64**	**0.54**	**0.61**
5-Year		**1.04**	**1.07**	**1.04**	**0.91**	**0.98**	**0.75**	**0.61**	**0.55**	**0.44**	**0.52**
10-Year		**0.85**	**0.87**	**0.88**	**0.75**	**0.84**	**0.69**	**0.57**	**0.52**	**0.47**	**0.60**
	All except last t days										
Maturity	t =	1	2	3	4	5	6	7	8	9	10
2-Year		**0.53**	**0.43**	**0.35**	**0.37**	**0.34**	**0.40**	**0.43**	**0.46**	**0.48**	**0.43**
5-Year		**0.34**	**0.24**	**0.16**	**0.18**	**0.14**	**0.20**	**0.27**	**0.30**	**0.34**	**0.26**
10-Year		**0.27**	**0.19**	**0.11**	**0.14**	**0.09**	**0.11**	**0.18**	**0.17**	**0.18**	**0.04**

Notes: This table reports the annualized Sharpe ratios from holding the Treasury security over either the last t trading days of each month (upper panel), or all but the last t trading days of each month (lower panel). These are computed as the averages of excess returns in equations (1) and (2), divided by the standard deviation of these excess returns, and then multiplied by the square root of 12. The sample period is from 1990 to 2018.

Table 4.
Average Cumulative Excess Return by Five-Year Period

Maturity										
	1990-1994									
	Last t days									
t =	1	2	3	4	5	6	7	8	9	10
2-Year	0.02	0.05**	0.07***	0.08***	0.09***	0.06*	0.07*	0.07**	0.05	0.05
	(0.01)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.05)
5-Year	0.03	0.08	0.12*	0.17***	0.20***	0.10	0.09	0.09	0.04	0.05
	(0.04)	(0.05)	(0.07)	(0.06)	(0.07)	(0.08)	(0.09)	(0.09)	(0.10)	(0.11)
10-Year	0.06	0.09	0.15	0.25**	0.30**	0.18	0.15	0.13	0.04	0.14
	(0.07)	(0.10)	(0.13)	(0.12)	(0.13)	(0.16)	(0.18)	(0.19)	(0.19)	(0.22)
	1995-2000									
t =	1	2	3	4	5	6	7	8	9	10
2-Year	0.03**	0.03	0.03	0.01	0.05	0.03	0.03	0.02	-0.02	0.00
	(0.01)	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
5-Year	0.11**	0.11*	0.12	0.06	0.16*	0.11	0.08	0.08	-0.05	0.01
	(0.04)	(0.06)	(0.08)	(0.09)	(0.09)	(0.10)	(0.11)	(0.11)	(0.11)	(0.13)
10-Year	0.19**	0.22*	0.25*	0.15	0.34**	0.26	0.22	0.22	0.01	0.10
	(0.08)	(0.12)	(0.15)	(0.16)	(0.17)	(0.18)	(0.18)	(0.20)	(0.21)	(0.23)
	2000-2004									
t =	1	2	3	4	5	6	7	8	9	10
2-Year	0.04**	0.06**	0.07**	0.08**	0.09**	0.11**	0.09**	0.12**	0.14***	0.15***
	(0.02)	(0.02)	(0.03)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)
5-Year	0.13***	0.16***	0.18**	0.16*	0.16*	0.22**	0.20*	0.26**	0.30**	0.30**
	(0.04)	(0.06)	(0.07)	(0.09)	(0.10)	(0.11)	(0.11)	(0.11)	(0.12)	(0.13)
10-Year	0.22***	0.27**	0.30**	0.23	0.22	0.30	0.27	0.38**	0.46**	0.49**
	(0.07)	(0.11)	(0.13)	(0.16)	(0.17)	(0.19)	(0.18)	(0.19)	(0.20)	(0.22)
	2005-2009									
t =	1	2	3	4	5	6	7	8	9	10
2-Year	0.04**	0.07***	0.07***	0.07**	0.06*	0.04	0.03	0.02	0.04	0.07
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)
5-Year	0.11**	0.18***	0.16**	0.16*	0.12	0.08	0.04	-0.01	0.06	0.17
	(0.05)	(0.06)	(0.08)	(0.08)	(0.08)	(0.10)	(0.11)	(0.12)	(0.12)	(0.14)
10-Year	0.13	0.26**	0.21	0.20	0.12	0.10	0.02	-0.03	0.13	0.39
	(0.10)	(0.11)	(0.15)	(0.16)	(0.16)	(0.20)	(0.22)	(0.25)	(0.26)	(0.31)
	2010-2014									
t =	1	2	3	4	5	6	7	8	9	10
2-Year	0.03***	0.05***	0.06***	0.06***	0.06***	0.05***	0.05***	0.05***	0.04***	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
5-Year	0.09***	0.17***	0.19***	0.21***	0.24***	0.22***	0.20***	0.16**	0.15*	0.16*
	(0.03)	(0.04)	(0.05)	(0.06)	(0.06)	(0.06)	(0.07)	(0.08)	(0.08)	(0.09)
10-Year	0.11*	0.28***	0.33***	0.35***	0.42***	0.43***	0.41***	0.40**	0.41**	0.45**
	(0.07)	(0.10)	(0.11)	(0.13)	(0.13)	(0.15)	(0.16)	(0.17)	(0.18)	(0.20)
	2015-2019									
t =	1	2	3	4	5	6	7	8	9	10
2-Year	0.01*	0.01	0.04***	0.03**	0.03*	0.03*	0.04**	0.03	0.02	0.03
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
5-Year	0.06**	0.05	0.14***	0.13***	0.14**	0.15**	0.16**	0.13**	0.11	0.13
	(0.02)	(0.04)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.08)
10-Year	0.13***	0.08	0.27***	0.24**	0.28**	0.29**	0.31**	0.26*	0.21	0.23
	(0.04)	(0.07)	(0.10)	(0.11)	(0.13)	(0.13)	(0.14)	(0.14)	(0.15)	(0.16)

Notes: This table reports the average excess returns from holding the 2-, 5-, and 10-year zero coupon security, as in equation (1), for the last 2 days of the month, broken out by subperiod. Standard errors are included in brackets.

Table 5.
Daily Excess Returns by *j*-to-Last Day of Month

	j -to-last day of month									
	Month End Average									
Maturity *j* =	1	2	3	4	5	6	7	8	9	10
2-Year	**0.03***	**0.02***	**0.01***	0.00	0.00	-0.01	0.00	0.00	0.00	**0.01**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
5-Year	**0.09***	**0.04**	**0.02**	0.00	**0.02**	-0.02	-0.02	-0.01	-0.01	**0.03**
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
10-Year	**0.14***	**0.06**	**0.05**	-0.01	**0.03**	-0.01	-0.03	-0.01	0.00	**0.08**
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
	Quarter End Average									
Maturity *j* =	1	2	3	4	5	6	7	8	9	10
2-Year	**0.03***	**0.02**	**0.02**	-0.01	**0.01**	0.00	0.00	0.00	-0.01	**0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
5-Year	**0.06**	**0.05***	**0.04***	-0.01	**0.01**	-0.02	**0.01**	-0.01	-0.03	**0.06***
	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)
10-Year	**0.07**	**0.05**	**0.08***	-0.01	**0.01**	-0.03	**0.04**	0.00	0.00	**0.13***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.07)

Notes: This table reports the average daily excess return from holding the 2-, 5-, and 10-year zero coupon Treasury note, earned on the *j*-to-last day of the month. The top panel shows an average over all months in the year. The bottom panel shows an average over quarter ends. Positive estimates are bolded for emphasis. The sample period is from 1990 to 2018.

Table 6.
Daily Average Excess Returns by Month

j-to-last day of month

January

Maturity	*j* = 1	2	3	4	5
2-Year	**0.03****	**0.03***	0.00	0.00	-0.02
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
5-Year	**0.15*****	**0.05**	0.00	**0.02**	-0.06
	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)
10-Year	**0.27*****	**0.11**	**0.01**	**0.07**	-0.13
	(0.08)	(0.10)	(0.11)	(0.09)	(0.11)

February

Maturity	*j* = 1	2	3	4	5
2-Year	**0.02**	**0.01**	-0.01	**0.02**	**0.01**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
5-Year	**0.06**	**0.02**	-0.01	**0.08**	**0.04**
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
10-Year	**0.08**	**0.07**	-0.02	**0.18***	**0.10**
	(0.10)	(0.11)	(0.12)	(0.10)	(0.10)

March

Maturity	*j* = 1	2	3	4	5
2-Year	**0.03*****	**0.02**	**0.01**	-0.03	0.00
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)
5-Year	**0.10****	**0.04**	**0.01**	-0.10*	-0.04
	(0.04)	(0.05)	(0.04)	(0.05)	(0.03)
10-Year	**0.10**	-0.01	-0.01	-0.19**	-0.10
	(0.08)	(0.10)	(0.08)	(0.09)	(0.08)

April

Maturity	*j* = 1	2	3	4	5
2-Year	**0.02**	0.00	0.00	-0.02	0.00
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
5-Year	**0.07**	-0.01	0.00	-0.06	0.00
	(0.05)	(0.06)	(0.04)	(0.06)	(0.04)
10-Year	**0.13**	-0.08	-0.01	-0.11	**0.01**
	(0.10)	(0.11)	(0.08)	(0.10)	(0.08)

May

Maturity	*j* = 1	2	3	4	5
2-Year	**0.01**	0.00	**0.02**	-0.01	**0.01**
	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
5-Year	**0.06**	**0.01**	**0.05**	-0.04	**0.04**
	(0.05)	(0.05)	(0.06)	(0.04)	(0.04)
10-Year	**0.12**	**0.10**	**0.05**	-0.09	**0.10**
	(0.11)	(0.10)	(0.12)	(0.11)	(0.09)

June

Maturity	*j* = 1	2	3	4	5
2-Year	**0.05****	**0.01**	0.00	0.00	**0.02**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
5-Year	**0.09***	**0.04**	-0.01	**0.02**	**0.07**
	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)
10-Year	**0.08**	**0.03**	-0.02	**0.04**	**0.09**
	(0.10)	(0.12)	(0.12)	(0.10)	(0.11)

July

Maturity	*j* = 1	2	3	4	5
2-Year	**0.06****	**0.02**	-0.01	**0.02**	-0.01
	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)
5-Year	**0.22*****	**0.04**	-0.03	**0.03**	-0.01
	(0.07)	(0.05)	(0.06)	(0.05)	(0.04)
10-Year	**0.38*****	**0.09**	-0.06	**0.01**	-0.03
	(0.14)	(0.09)	(0.11)	(0.09)	(0.08)

August

Maturity	*j* = 1	2	3	4	5
2-Year	**0.01**	**0.05*****	**0.01**	**0.02**	**0.01**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
5-Year	**0.05**	**0.13*****	**0.01**	**0.05**	**0.08**
	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
10-Year	**0.06**	**0.24****	**0.01**	**0.05**	**0.16**
	(0.10)	(0.10)	(0.12)	(0.09)	(0.12)

September

Maturity	*j* = 1	2	3	4	5
2-Year	**0.02**	**0.03**	**0.03*****	0.00	**0.03**
	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)
5-Year	**0.03**	**0.07**	**0.06***	**0.02**	**0.08****
	(0.07)	(0.07)	(0.03)	(0.05)	(0.04)
10-Year	**0.08**	**0.13**	**0.14***	**0.06**	**0.14***
	(0.13)	(0.12)	(0.08)	(0.11)	(0.08)

October

Maturity	*j* = 1	2	3	4	5
2-Year	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
5-Year	**0.09**	**0.06**	**0.03**	**0.02**	**0.01**
	(0.06)	(0.05)	(0.07)	(0.05)	(0.05)
10-Year	**0.22***	**0.08**	**0.05**	-0.09	**0.04**
	(0.12)	(0.10)	(0.14)	(0.10)	(0.09)

November

Maturity	*j* = 1	2	3	4	5
2-Year	**0.04****	0.00	**0.01**	-0.02	0.00
	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)
5-Year	**0.11****	-0.02	**0.08**	-0.06	**0.04**
	(0.05)	(0.07)	(0.06)	(0.06)	(0.05)
10-Year	**0.13**	-0.07	**0.22****	-0.13	**0.13**
	(0.10)	(0.13)	(0.10)	(0.10)	(0.11)

December

Maturity	*j* = 1	2	3	4	5
2-Year	**0.02**	**0.03*****	**0.04****	0.00	-0.01
	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
5-Year	**0.03**	**0.05**	**0.11****	0.00	-0.06
	(0.05)	(0.03)	(0.05)	(0.04)	(0.04)
10-Year	**0.01**	**0.06**	**0.21***	**0.03**	-0.08
	(0.12)	(0.07)	(0.11)	(0.09)	(0.09)

Maturity		H_0: All equal (p-value)						H_0: Equal to 0 (p-value)				
		j-to-last day of month						j-to-last day of month				
	j =	1	2	3	4	5	j =	1	2	3	4	5
2-Year		0.81	0.83	0.74	0.61	0.89		0.13	0.77	0.81	0.35	0.85
5-Year		0.49	0.89	0.77	0.42	0.36		0.00	0.76	0.80	0.42	0.43
10-Year		0.54	0.73	0.72	0.31	0.35		0.01	0.61	0.70	0.31	0.39

Notes: The upper panels of this table report the average excess returns from holding the 2-, 5-, and 10-year zero coupon Treasury note on the j-to-last day of the month, broken out by month. Standard errors are included in brackets. The bottom-most panel give p-values for F tests of the hypotheses that all the monthly coefficients are equal to each other, and that all the monthly coefficients are jointly equal to zero. The sample period is from 1990 to 2018.

Table 7.
Daily Average Excess Returns for On-the-Run Treasury Securities

Estimate

Maturity	*j*-to-last day of month, j = 1	2	3	4	5	6	7	8	9	10
2-Year	**0.02*** **	**0.01** **	**0.01***	0.00	**0.01***	0.00	0.00	0.00	0.00	**0.01***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
5-Year	**0.08*** **	**0.05*** **	0.00	0.00	**0.02**	-0.01	-0.02	-0.01	0.00	**0.02**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
10-Year	**0.13*** **	**0.07*** **	**0.03**	**0.01**	**0.04**	-0.01	-0.03	0.00	0.00	**0.04***
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
30-Year	**0.25*** **	**0.12** **	**0.08**	**0.01**	**0.06**	0.00	-0.03	-0.01	0.00	**0.09***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)

Sharpe Ratio

Maturity	*j*-to-last day of month, j = 1	2	3	4	5	6	7	8	9	10
2-Year	**0.78**	**0.47**	**0.37**	-0.07	**0.42**	-0.13	-0.08	-0.01	**0.12**	**0.35**
5-Year	**1.01**	**0.58**	**0.05**	**0.04**	**0.37**	-0.14	-0.28	-0.07	-0.05	**0.25**
10-Year	**1.02**	**0.50**	**0.25**	**0.04**	**0.34**	-0.07	-0.22	**0.03**	-0.04	**0.31**
30-Year	**1.02**	**0.51**	**0.31**	**0.03**	**0.30**	-0.01	-0.13	-0.02	-0.01	**0.38**

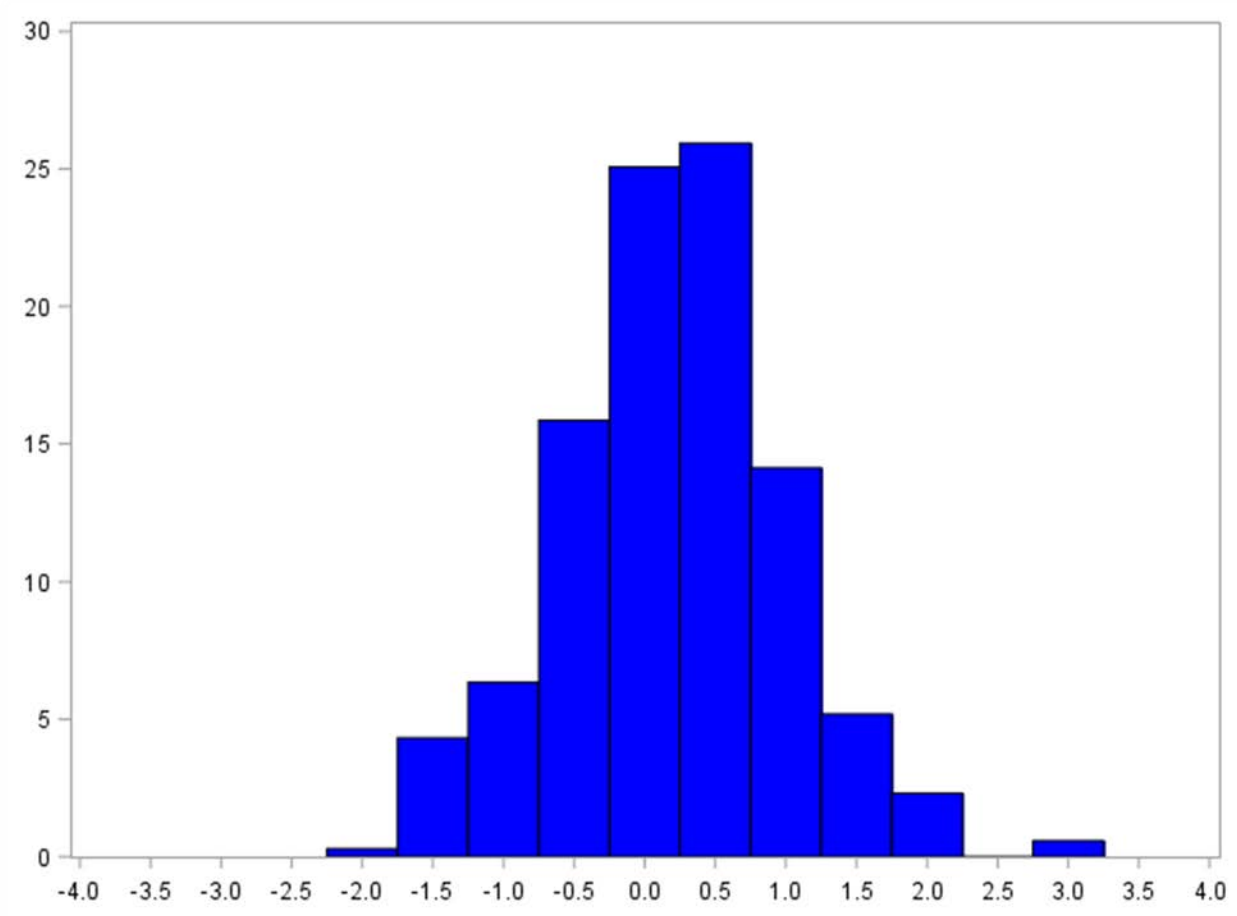
Notes: The upper panel of this table reports the average excess return estimates from holding the 2-, 5-, 10- and 30-year on-the-run Treasury note on the j-to-last day of the month, after controlling for dates around Treasury auctions. Specifically, the estimates are formed with a separate time series regression for each maturity of daily excess returns onto dummies indicating the number of trading days till the last day of the month (0-22) and 7 dummies for a note auction day and dummies for an auction that there is a note auction on 1-3 days previously or later. Coefficient estimates for the auction day dummies are omitted. Standard errors are included in brackets. Units are approximate percentage points. The lower panel reports the annualized Sharpe ratios from holding the on-the-run Treasury security on the j-to-last day of the month. These are computed as the averages of excess return estimates reported in the top panel divided by the standard deviation of the sample-average excess returns, and then multiplied by the square root of 12. Positive values are bolded for emphasis. The sample period is from 1990 to 2018.

Table 8.
Treasury Futures and Interest Rate Swaps over the Last *t* Days of the Month

	Treasury Futures									
	Last *t* days									
Contract *t* =	1	2	3	4	5	6	7	8	9	10
5-Year	**0.07*** **	**0.10*** **	**0.12*** **	**0.12*** **	**0.15*** **	**0.13*** **	**0.02**	0.00	-0.01	**0.02**
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
10-Year	**0.09*** **	**0.14*** **	**0.17*** **	**0.18*** **	**0.22*** **	**0.20*** **	-0.06	-0.08*	-0.10**	-0.04
	(0.01)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)
30-Year	**0.15*** **	**0.21*** **	**0.27*** **	**0.27*** **	**0.33*** **	**0.31*** **	**0.03**	**0.03**	**0.02**	**0.09**
	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.06)	(0.07)	(0.07)	(0.07)
	Interest Rate Swaps									
	Last *t* days									
Maturity *t* =	1	2	3	4	5	6	7	8	9	10
2-Year	-1.10***	-1.63***	-2.11***	-2.24***	-1.94***	-1.62**	-0.86	-0.73	-0.59	-0.72
	(0.30)	(0.44)	(0.52)	(0.61)	(0.65)	(0.73)	(0.76)	(0.81)	(0.86)	(0.95)
5-Year	-1.63***	-2.32***	-2.56***	-2.43***	-2.46***	-2.26***	-1.45*	-1.19	-1.01	-1.33
	(0.31)	(0.47)	(0.56)	(0.63)	(0.70)	(0.77)	(0.82)	(0.85)	(0.90)	(1.01)
10-Year	-1.61***	-2.23***	-2.52***	-2.41***	-2.45***	-2.35***	-1.80**	-1.68**	-1.65*	-2.12**
	(0.31)	(0.46)	(0.54)	(0.61)	(0.66)	(0.73)	(0.80)	(0.83)	(0.87)	(0.97)

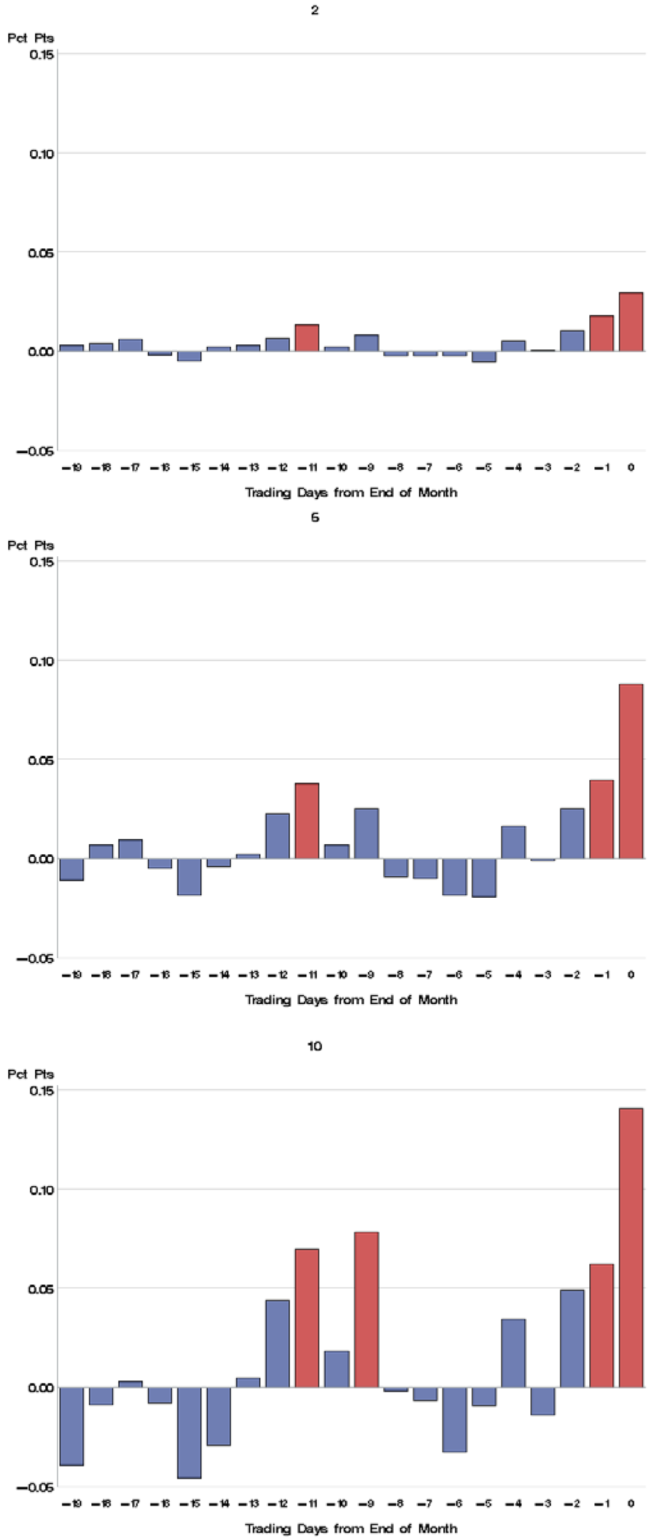
Notes: The top panel of this table reports 100 times the average returns on long positions on Treasury futures contracts held only over the last *t* days of the month, for different choices of m and different futures contracts. The units are (approximate) percentage points per month (not annualized). Positive estimates are bolded for emphasis. The lower panel of this table reports average changes in swap rates from m days before the last day of the month to the last day of the month. Units are basis points. The sample period is from 1990 to 2018. Standard errors are shown in brackets.

Figure 1.
Excess Return Density for 10-Year Treasury Security over Last Two Days of Month



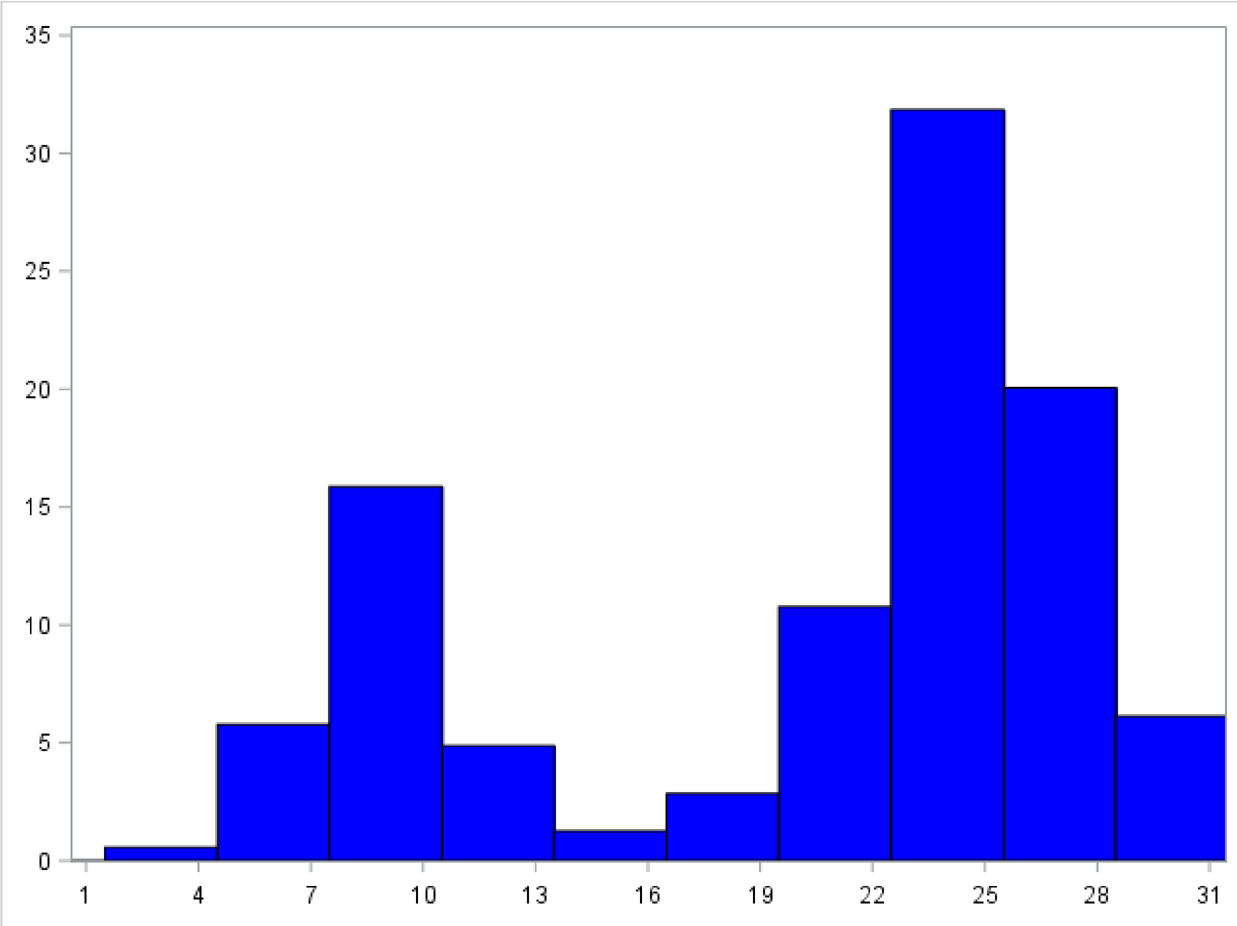
Notes. This figure shows a histogram of the average cumulative excess returns for the 10-year Treasury note over the last 2 days of the month.

Figure 2.
Average One-Day Excess Return for 2-, 5-, and 10-Year Maturity



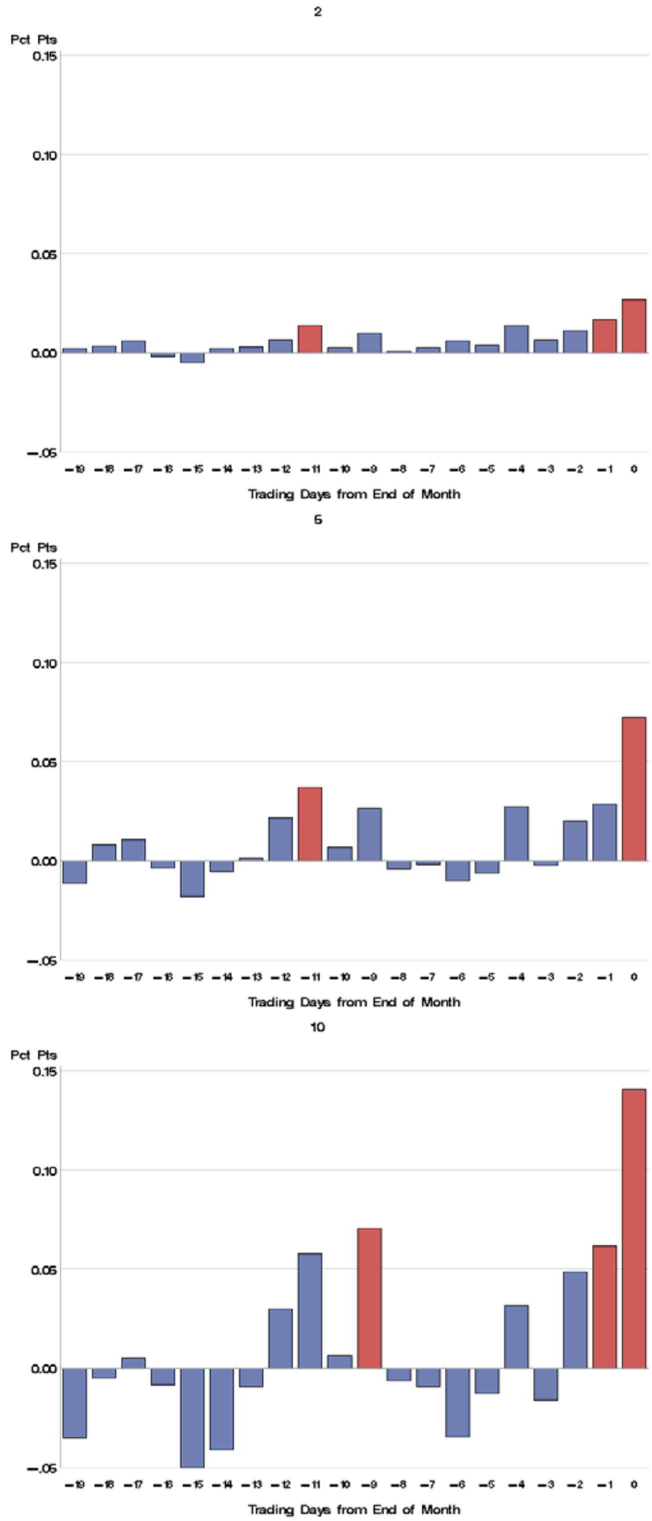
Notes: This figure plots 100 times the average daily excess return on a zero coupon Treasury note earned *t* days from the end of the month: the rightmost bar is the average excess return on the last day of the month. The top, center, and lower panels show the 2-, 5-, and 10-year zero coupon note maturities, respectively. Units are approximate percentage points. The sample period is from 1990 to 2018. Bars in blue are not statistically significant at the 5 percent level; those in red are statistically significant at that level.

Figure 3.
Note Auctions by Day of Month



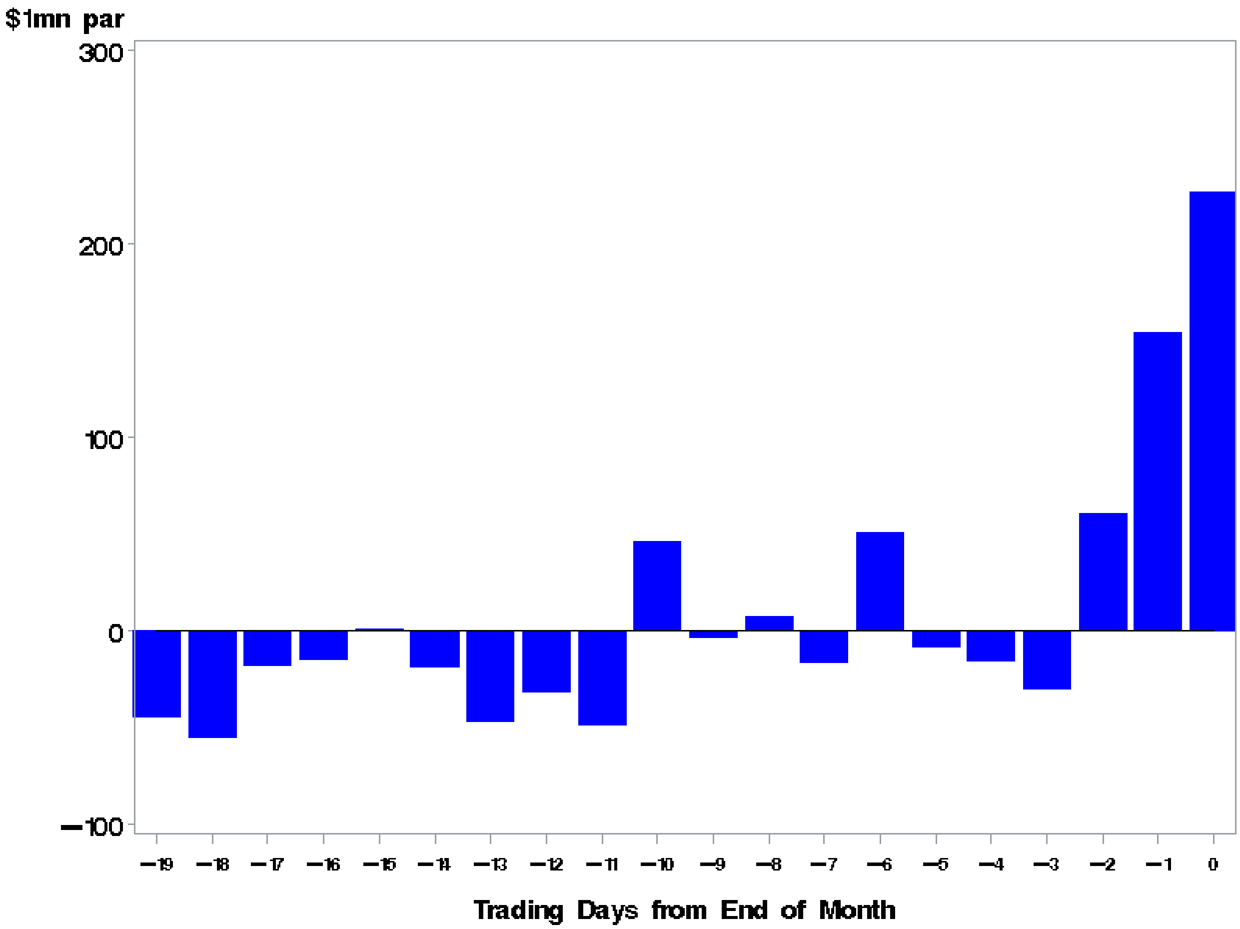
Notes: This figure plots the histogram of all US Treasury note auctions since 1990 by day of the month. For example, the entry for 20 is the number of note auctions that occurred on the 20th of the month.

Figure 4.
Average One-Day Excess Return for 2-, 5-, and 10-Year Maturity, Controlling for Auction Dates



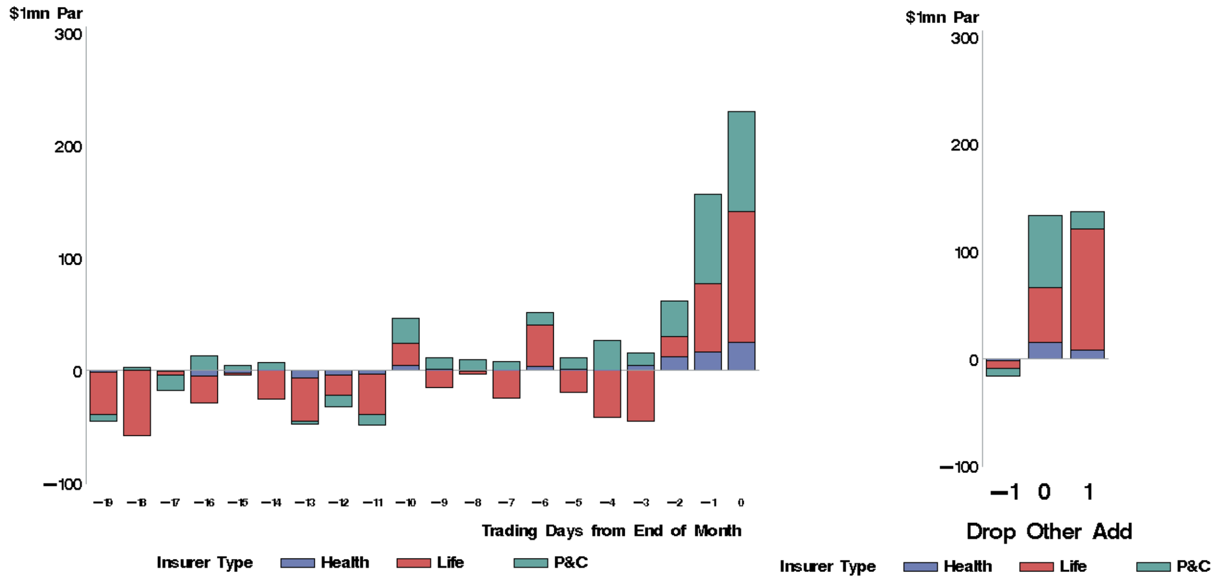
Notes: This figure is based on a regression of 100 times daily excess returns for 2-, 5-, and 10-year zero coupon Treasury securities, in the top, center, and lower panels, respectively, onto dummies indicating the number of trading days till the last day of the month (0-19) and 7 dummies for a note auction day and dummies for an auction that there is a note auction on 1-3 days previously or later. Each maturity is estimated separately. Coefficient estimates for the day dummies are omitted, Units are approximate percentage points. The sample period is from 1990-2018. Bars in blue are not statistically significant at the 5 percent level; those in red are statistically significant at that level.

Figure 5.
Daily Average Net Purchases (Aggregate)



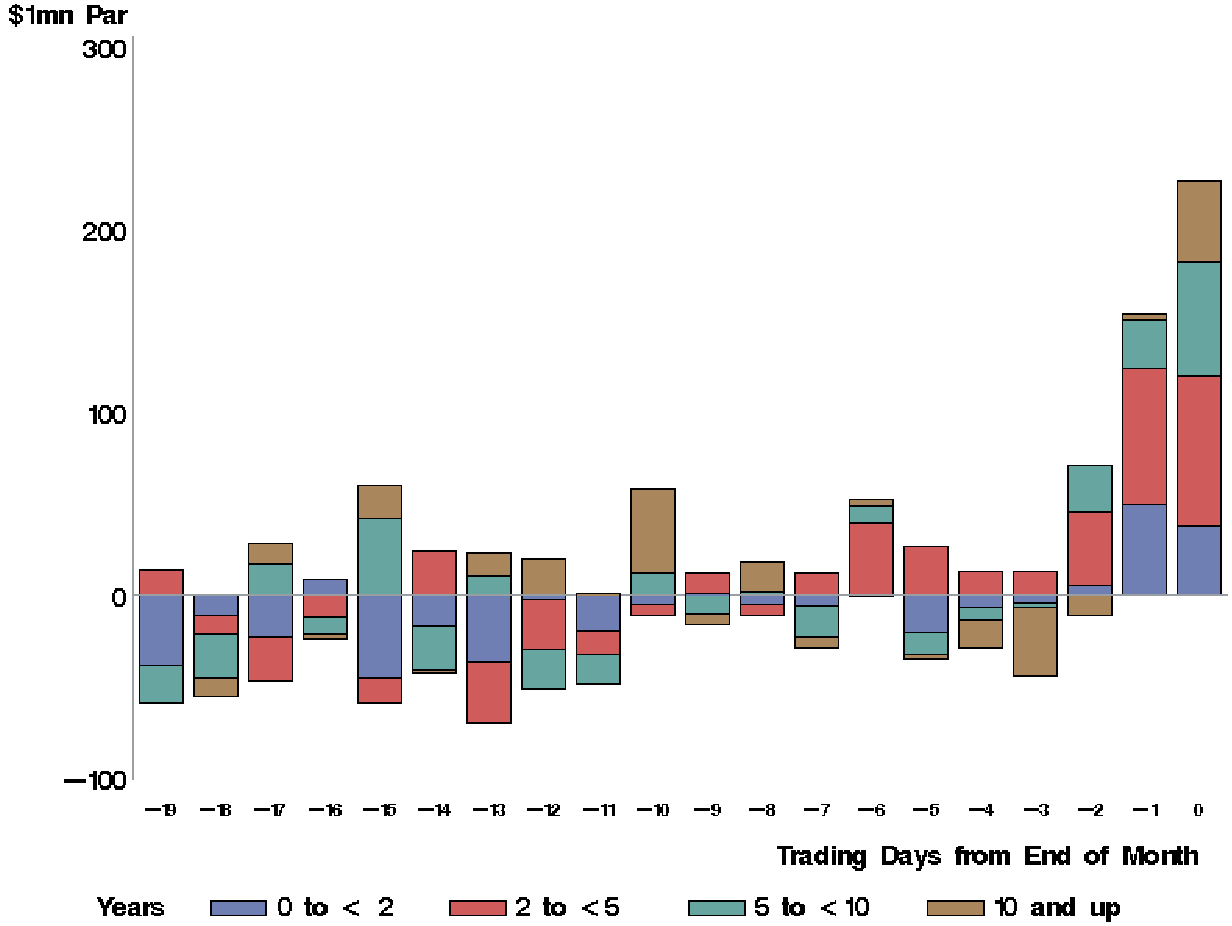
Notes: This figure reports the average net purchases of Treasuries by trading days to the end of the month for all U.S. registered insurers. Units are million dollars par value. The sample period is from 1990 to 2016.

Figure 6.
Daily Average Net Purchases (by Insurer Type)



Notes: This figure reports the average net purchases of Treasuries by U.S. registered insurers, broken out by insurer type. The left panel shows net purchases by trading days to the end of the month. The right panel shows net purchases on the last day of the month of securities dropped from the Bloomberg Barclays Government Bond Index (denoted -1), securities neither added nor dropped from the index (0), and securities added to the index (1). Units are million dollars par value. The sample period is from 1990 to 2016.

Figure 7.
Daily Average Net Purchases (by Duration)



Notes: This figure reports the average net purchases of Treasuries by trading days to the end of the month for all U.S. registered insurers. Purchases are broken out by duration bucket. Units are million dollars par value. The sample period is from 1990 to 2016.