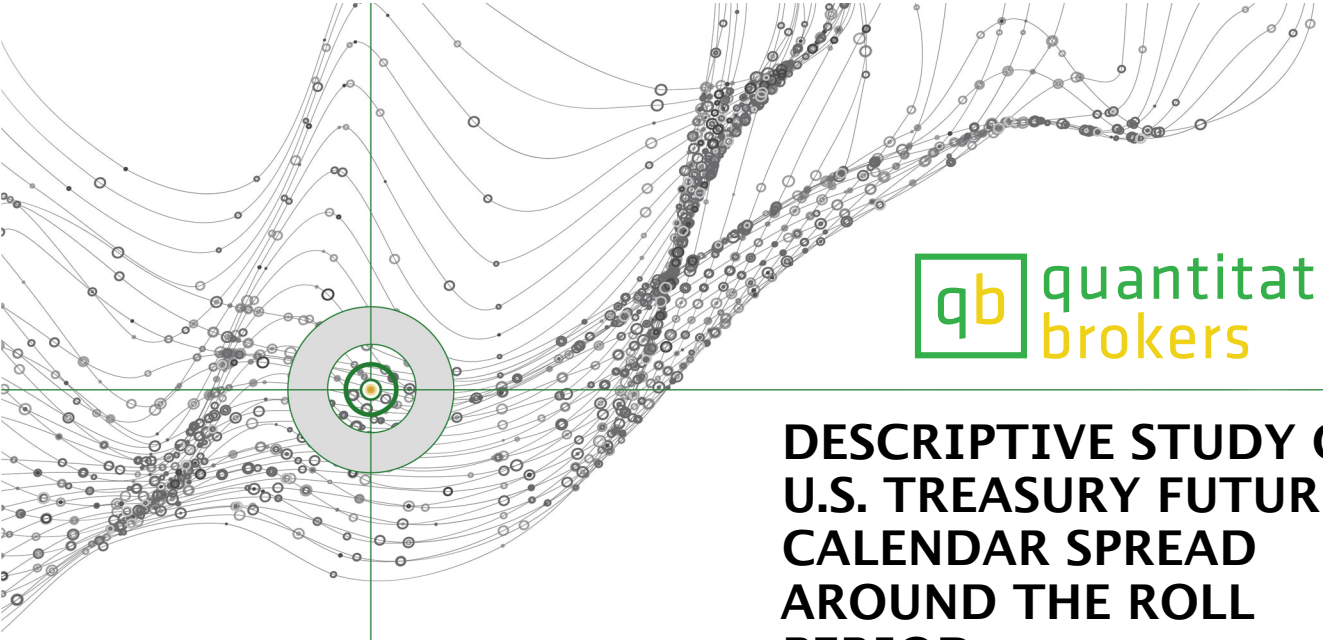

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DESCRIPTIVE STUDY OF U.S. TREASURY FUTURES' CALENDAR SPREAD AROUND THE ROLL PERIOD

REZA GHOLIZADEH
SHANKAR NARAYANAN
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Using end of the day settlement prices from 1980 – 2018 of U.S. Treasury futures, we study the characteristics of the calendar spread around the roll periods. This is the time when most market participants roll their exposure from the soon to be expiring contract to the next one, generally in the ten days prior to and including the "first intention day" (when the exchange gives notice of delivery). We conduct a descriptive analysis of a few variables for these roll periods built upon our intuition and experience. We study whether trading activity during the beginning of the roll period has any predictive power for the remainder of the roll duration. In addition, we examine the reversion in the calendar spread after the roll period as it is indicative of market impact. Lastly, we look for changes in the spread in the week prior to the roll period. QB's earlier research [2013] on this topic showed evidence of auto-correlation in the change in the calendar spread between the rolls using the last few years of data. Academic literature in this space is limited and most sell-side firms' view of the Treasury futures' spread movement around the roll periods is formed using samples from recent time periods of historically low levels in Treasury yields. To our knowledge, Russell [2018] was the only earlier research work on the Treasury rolls that used data from the 1980s and therefore was comprehensive as it included periods of low as well as high interest rates. Russell applied iterative regression techniques to forecast the dynamics of the calendar spread during the roll periods but his results were primarily applicable to the 10-Year futures. Our dataset similar to that of Russell's includes different regimes of market conditions. We use simpler methods but our findings are statistically more robust and economically more appealing, as well as consistent across all instruments and time periods.

We calculate the spread SP $= P_f - P_b$, which is the difference between the settlement prices of the front month or active contract (P_f) and back month or deferred contract (P_b). Although duration-neutral rolls are more relevant economically, we have chosen to model the one-to-one ratio as it is a listed instrument and gives stability across time periods to our estimates; the results, however are qualitatively similar for any reasonable ratio such as obtained from principal component analysis. The roll period is the ten trading days before and including the "first intention day" as specified by the CME. The settlement prices of the active and deferred contracts are End-of-Day datasets from CME DataMine. After cleaning, the longest history (from 1980) in our sample is for 30-Year Bond (**ZB**) futures and 10-Year Note (**ZN**) futures, whereas the sample is much smaller from 2010 for Ultra-Bond (**UB**) futures. While the data for 5-Year Note (**ZF**) futures and

2-Year Bill (**ZT**) futures is from 1990, there are also several missing records that have been omitted from our sample. The analysis presented in this article is for the full sample for most instruments but the patterns are consistent and in some cases even stronger when analyzed using the recent ten years of sample data.

On the next few pages, we show several plots regarding our analysis. In all the plots, the calendar spread and its changes are shown in unit ticks of the outrights which is $1/32^{nd}$ of a point. Figure 1 shows the time series of the average spread change for each instrument around the roll period, where $t = 0$ is the first intention day. Shown on the y-axis is SP(t) − SP(t=0). Interestingly, on average, the spread sharply narrows during the ten days of the roll period for all the instruments. Additionally, the average change in the spread during these ten days is a smooth downward movement. We see that the spread on average widens after the first intention day (from $t = 0$ to $t = +5$). These patterns have been further analyzed in figures 2, 3 and 4.

Figure 2 confirms the market impact on the calendar spread during the roll period. We observe strong negative correlation of -31% between the spread change during the last five days of the roll period ($t = -5$ to $t = 0$) with the change in spread during the five days after the roll period ($t = 0$ to $t = +5$); results are similar with the entire ten days of the roll period as the independent variable. Figure 3 is the scatter plot of change in the spread during first five days ($t = -10$ to $t = -5$) versus the change in spread in the last five days ($t = -5$ to $t = 0$) of the roll period. The correlation is around 18%. We believe that this strong positive relationship is due to serial correlation in the trading activity over the ten days of the roll period. As most traders roll over multiple days, this creates an order flow correlation from one day to the next and in turn drives the calendar spread in the same direction during the roll period. We use five days as an approximate time line for our analysis but our results are robust even when we separate the roll period into other sub-samples. Lastly, figure 4 shows mild negative correlation of around -5% across all the instruments of the change in calendar spread in the five days prior to the roll period ($t = -15$ to $t = -10$) with the spread change during the roll period ($t = -10$ to $t = 0$). We suppose that this weak relationship is on account of the price reversion in the liquid near contract that traders need to sell if long and vice versa during the roll. The correlation is strongest for ZN which is extremely liquid and more volatile than at least ZT and ZF.

Figure 5 shows the candlestick chart of 10-year futures' (ZN) calendar spread during the roll period since 1983. The red vertical bars are the periods when the calendar spread went down whereas the green vertical bars are the periods when the calendar spread went up during the roll period. The floor and top of the green bars (the top and floor of the red bars) respectively show the calendar spread on the $t = -10$ and $t = 0$ of the roll period. We can notice that the bars tend to cluster on average (red bars are followed by red and greens with the greens), which confirms the positive correlation between the changes in calendar spread during the roll cycles over the entire sample period. We can also see the drastic drop in the calendar spread during the three roll periods after the 2008 financial crisis; similarly spreads went up significantly during the few rolls prior to the September, 2008 crash. The horizontal line on the candlesticks is the calendar spread half way through the roll (around fifth day prior to the first intention day). In most instances, the horizontal bar is in between the start and end of the bar indicating

strong momentum in the direction of the spread from the start to the intention day, which in turn confirms our findings as reported in figure 2. One can also notice that spreads mostly narrowed in the last ten years during the roll periods, which could be due to money managers being predominantly long in falling interest rates environment and thus would have to sell the front month contract and buy the back month contract, causing the calendar spread to narrow during the rolls. The pattern shown here for ZN is also applicable for other instruments.

Figure 6 shows the roll period of June, 2018 where we observe patterns consistent with the historical analysis. The calendar spread falls during the ten days of the roll period and then widens after the roll period for ZN, ZT and ZF. The spread change in the last five days of the roll period has also been in the same direction as the first five days. Lastly, one can also notice a strong reversion in the calendar spread from five days prior to the roll event to the change in spread during the ten days of the roll period.

Based on our historical study and given that the market conditions are fairly similar to the June, 2018 roll period, **our current view for the September, 2018 roll (U8 to Z8)** is that the spreads will narrow (downward movement) during the roll period. This information is key in deciding how to manage the roll: for those who are long the front month contract, the suggestion is to roll early whereas those who are short the active contract should roll later. Nevertheless, our view for the upcoming roll of September 2018 would be strongest after the first few days of the roll period and we anticipate the calendar spread to move in the same direction as the spread movement during the first few days of the roll period. We also expect a strong mean reversion in the calendar spread after the first intention day, August 30^{th}, 2018. We recommend to observe the spread change during the five days prior to the roll event (around $t = -15$ to $t = -10$), especially for ZN. If the calendar spread is positive and wide, then we expect it to narrow during the entire ten days of the roll period.

Our recommendation for the upcoming roll is built upon the empirical analysis of almost 35 years of data and is consistent across all the instruments. Building a deeper understanding of the calendar spread during the roll period has implications for further development of our new "The Roll" algorithm[1] which we are also launching at this time. In our analysis, we could include filters on market conditions for forecasting the calendar spread change during the roll period and this will be part of our future research.

References

[1] QB Research (2013), "Treasury Roll Recommendation", *QB White Paper, August, 2013.*

[2] Russell S. (2018), "Predicting changes in the U.S. Treasury futures' calendar spread during the roll period", *Princeton University, Senior Thesis Supervised by Robert Almgren, Head of Research, QB.*

[1] The Roll strategy is designed to help improve execution of our clients' roll orders, particularly duration neutral rolls where there is a quantity imbalance between the legs. We have also created a new roll period benchmark and we are using this in new roll TCA reports for our clients, furthering their understanding of execution performance during this time.

FIGURE 1
$t = 0$ is the first intention day and $t = -10$ is the start of the roll period. While not shown,the correlation of change in calendar spread during the ten days of the roll with the previous roll period is around 17% across all the instruments

Average change in the calendar spread around the roll periods

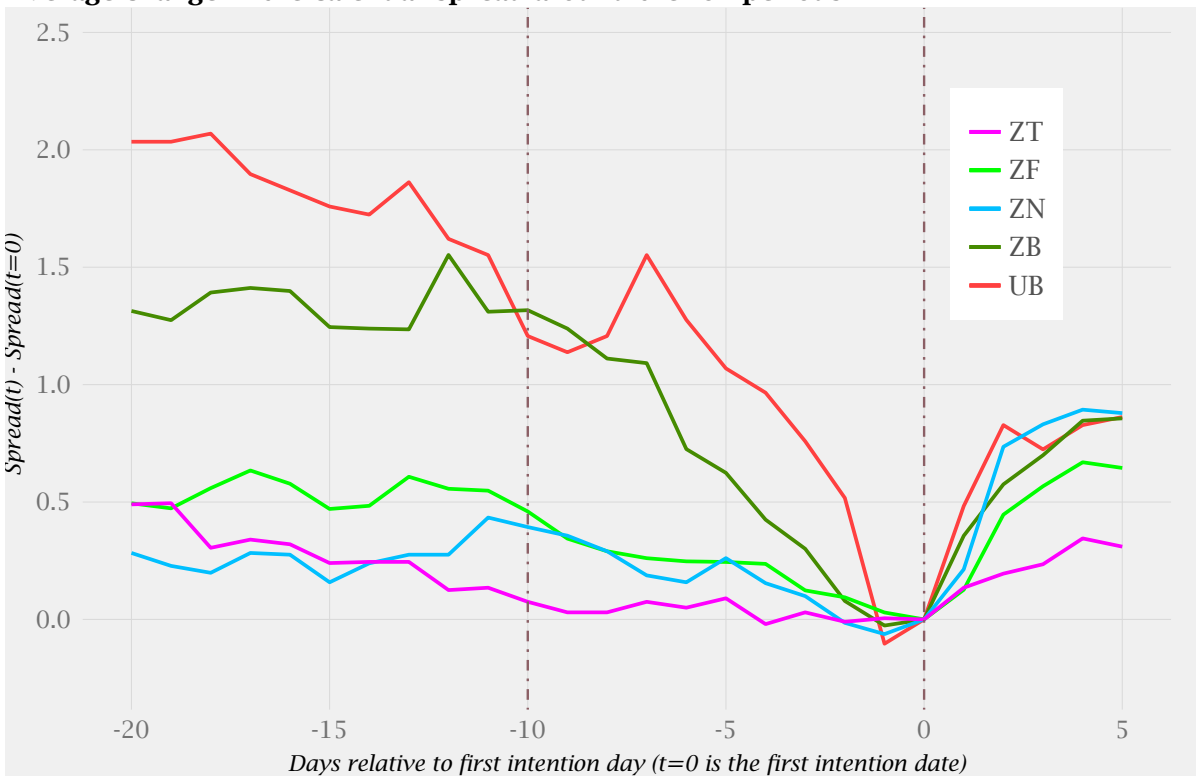

FIGURE 2
Change in calendar spread after the roll period ($t = 0$ to $t = +5$) is negatively correlated with the change in the calendar spread during the last five days of the roll ($t - 5$ to $t = 0$); demonstrates significant mean reversion in the calendar spread after the roll period

Strong reversion in the calendar spread after the roll periods

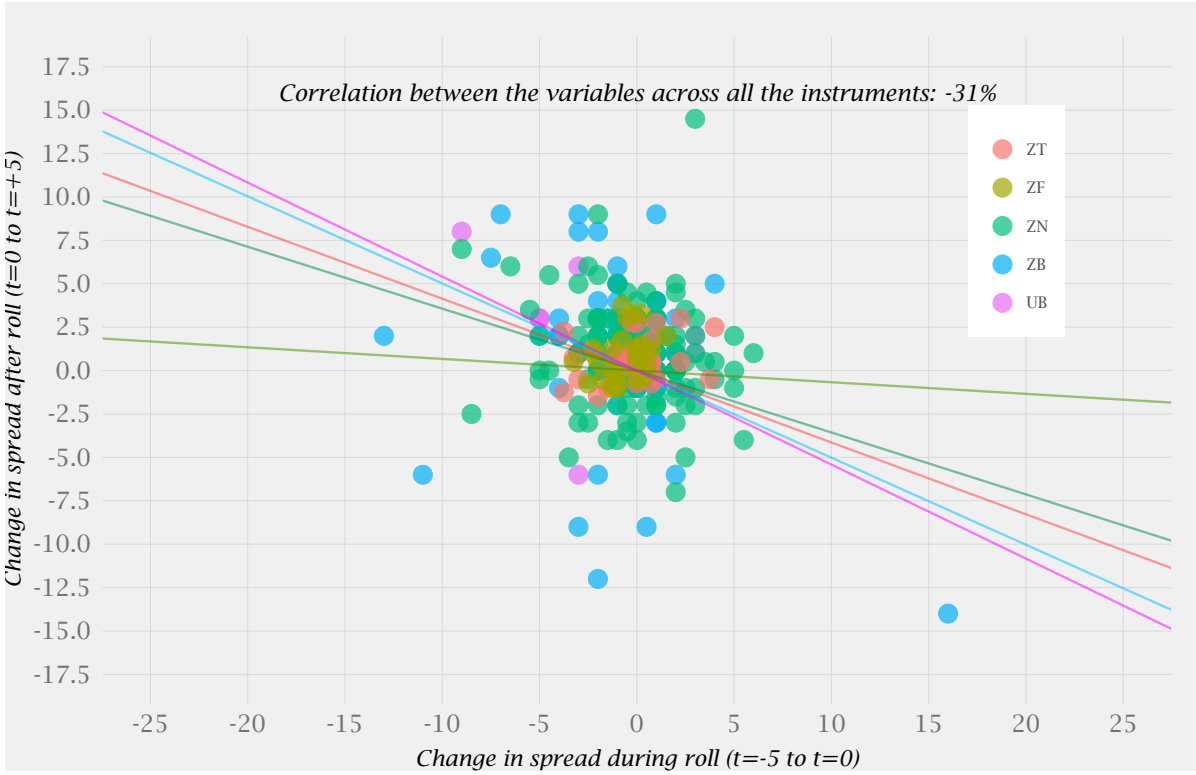

FIGURE 3
Change in calendar spread during the first five days of the roll period ($t = -10$ to $t = -5$) is positively correlated with the last five days of the roll ($t = -5$ to $t = 0$), where $t = 0$ is the first intention day

Momentum in the calendar spread during the roll periods

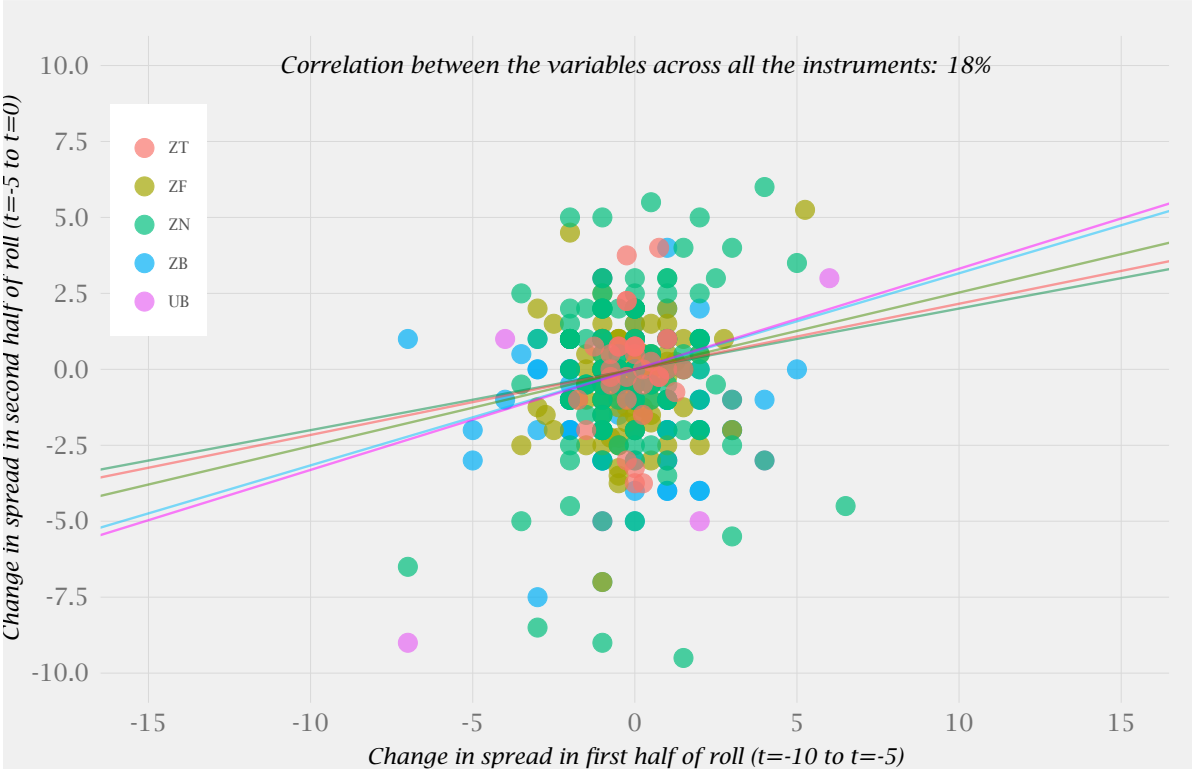

FIGURE 4
There is a weak negative correlation between the change in calendar spread during the five days prior to the roll period ($t = -15$ to $t = -10$) with the ten days of the roll period ($t = -10$ to $t = 0$), where $t = 0$ is the first intention day

Weak reversion in the calendar spread going into the roll periods

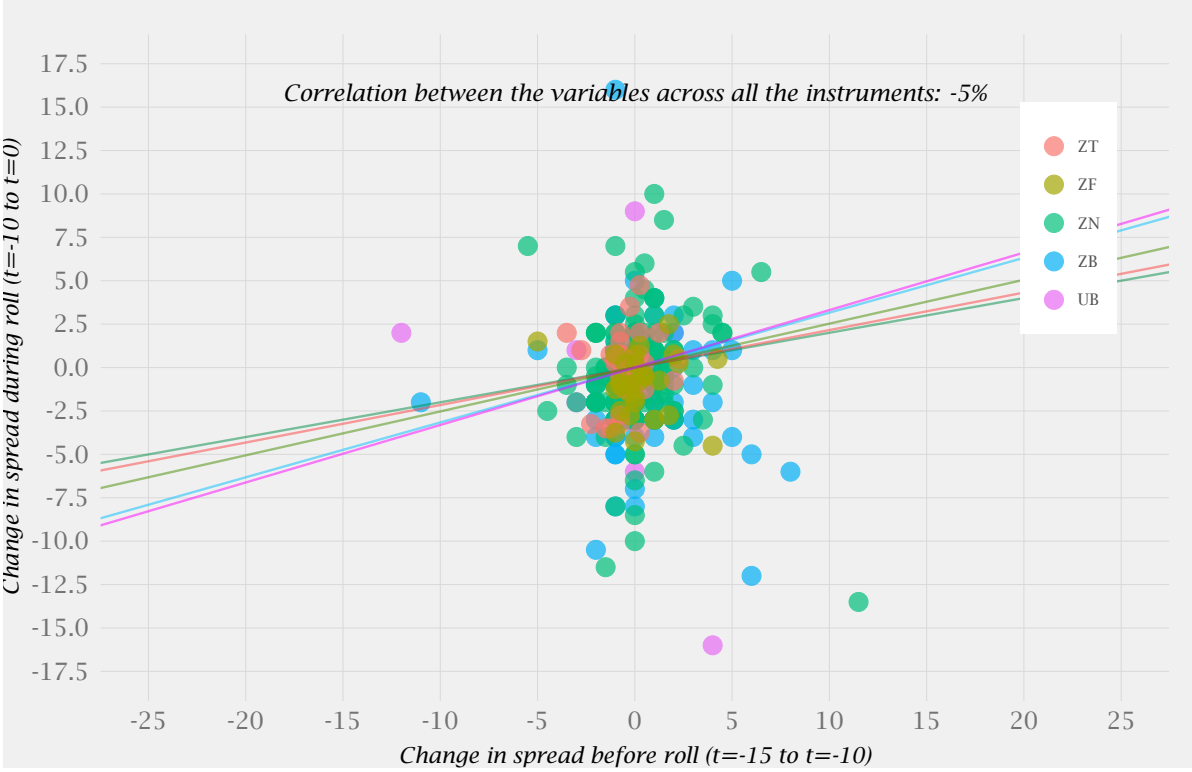

FIGURE 5
The candle bars show the open, high, low and close of the calendar spread around the ten days of the roll period. The calendar spread on the fifth day prior to intention day in most instances is between the open (first day) and close (last day) of the roll. The blue jagged line is the 10-Year yield. The pattern is similar for other instruments

10-Year futures' calendar spread around the roll periods

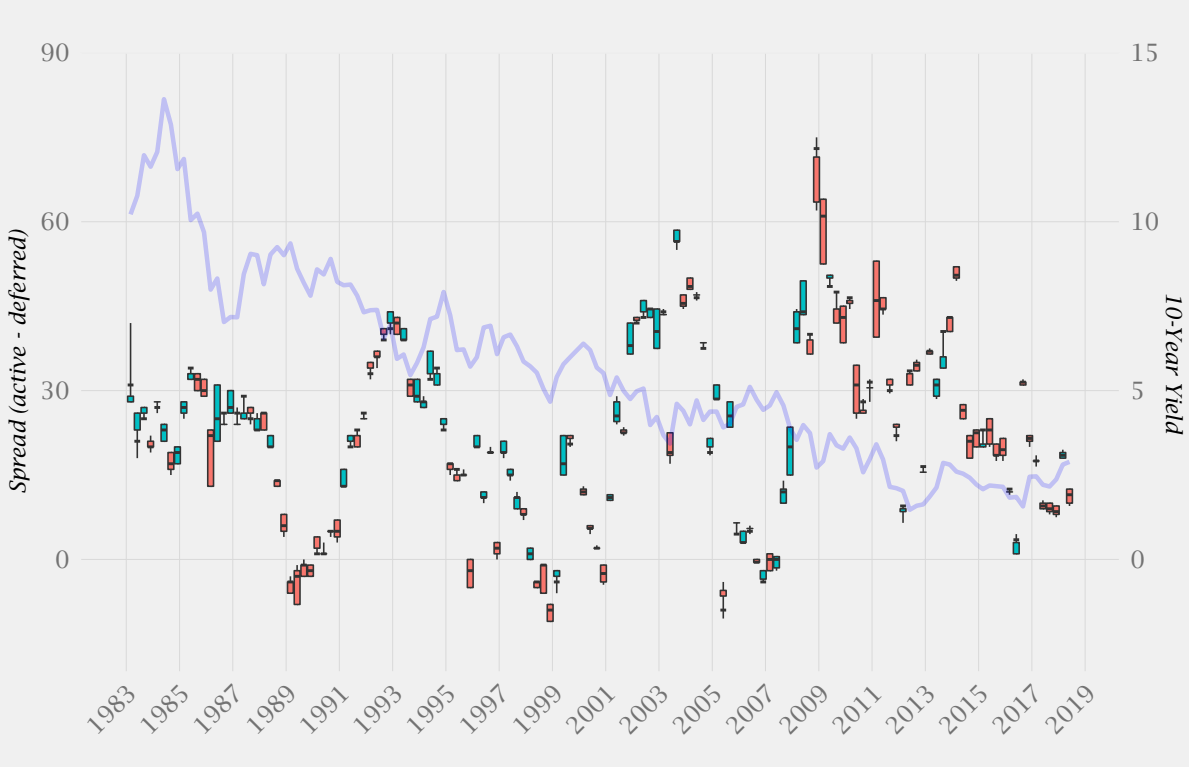

FIGURE 6
The calendar spread begins to narrow for the 10-year, 5-year and 2-year futures from around May 16^{th}, 2018, which was the tenth trading day prior to the first intention day of May 30^{th}, 2018. The Ultra bond and 30-year futures were relatively flat

June, 2018 roll from M8 to U8