Can Demand Shocks For Treasuries Inform Us About Monetary Policy?†

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Abstract

Treasury auctions of ten-year notes provide a natural way to isolate exogenous changes in longer-term interest rates that are orthogonal to conventional monetary policy shocks. On auction days, unforeseen variations in demand for ten-year Treasuries create a preferred-habitat-like effect on the yield curve and increase the term premium, consistent with the duration channel. Using auction-day surprises as an instrument, I identify shocks to longer-term interest rates that mimic shocks to the Fed's balance sheet policies. I estimate that the Fed's asset purchases sharply reduce credit spreads and generate a persistent improvement in economic activity. Using this alternative identification, I demonstrate the link between balance sheet policies, economic activity, and interest rates that previous work has been unable to show empirically.

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1 Introduction

Since 2009, the role of long-term interest rates as a policy instrument has moved to the center of macroeconomic discourse. Following the 2008-2009 financial crisis and the COVID-19 pandemic, central banks across the world have turned to Large-Scale Asset Purchase (LSAP) programs to explicitly stimulate the long end of the yield curve after fully utilizing conventional tools like the federal funds rate and forward guidance. More recently, escalating concerns over debt sustainability have kept the dynamics of ten-year yields at the forefront of policy debates.

The institutional structure of U.S. Treasury auctions provides a unique laboratory for isolating exogenous variations in long-term interest rates. While tentative six-month auction schedules are released at Quarterly Refunding Conferences, specific auction details—such as volume and terms—are finalized four to seven days before the event. With the supply of securities fixed and publicly available in advance, any innovation in futures yields within a tight thirty-minute window bracketing the auction closure thus reflects unforeseen fluctuations in investor demand for Treasuries.

Since the auction schedule(s) is not guided by the dual mandate of price stability and full employment (unlike monetary policy), and the likelihood of release of any other news or event in that tight window is extremely small, it is possible to conclude that such changes are driven by demand shocks for Treasuries. Moreover, unlike supply shocks to Treasuries identified using a similar approach around a thirty-minute window bracketing the announcement details of the auction schedule, which can be linked to the fiscal stance of the government, auction day surprises truly capture a demand shock from investors, as the time between auction detail-announcement and auction implementation gives market participants sufficient time to react to these fiscal-related considerations and the expected yields right before auction closure already incorporates these effects. Thus, by the time the auction closes, fiscal considerations are already 'priced in', leaving the residual volatility to represent pure demand-driven innovations.

Unforeseen changes in the demand for Treasuries during auctions, typically caused by shifts in investor preferences (such as flight to safety, changes in perceptions about convenience yields, portfolio re-balancing between equity and bonds, or even balance sheet constraints faced by primary dealers), explain significant high-frequency variation across zero-coupon yields, forward rates, and corporate bond yields. The results reveal a 'Preferred Habitat' effect: the impact of a demand shock for a ten-year Treasury is concentrated around a neighborhood of the ten-year maturity mark - most of the impact concentrated in the 7-20 year maturity space and tapers off as one moves toward either the short or the ultra-long end of the curve. Additionally, an unforeseen change in demand

for the ten-year Treasury is mainly transmitted through changes in the term premium across the yield curve.

In this way the impact of demand shocks for Treasuries, is equivalent to the impact of Large Scale Asset Purchases (LSAPs) by the Fed whereby at it's core, shocks via LSAPs represent an announcement of unforeseen demand for longer-term Treasuries and assets by the Fed, which then via the announcement effect generates changes in long term yields which operate by compressing term premiums spilling over to a reduction in borrowing costs for households and firms in the economy. Thus, these auction-day surprises serve as an ideal high-frequency proxy for the 'quantity' shocks inherent in balance sheet policies. More generally, the effects examined via changes in the demand for Treasuries can be viewed as the impact of unanticipated fluctuations in longer-term interest rates. Although unforeseen changes in the demand for ten-year Treasuries

While high-frequency identification ensures orthogonality with other macro shocks, transitioning to a monthly frequency introduces the possibility that FOMC meetings and Treasury auctions occur in the same month. To isolate a measure of long-term rates that remains representative of LSAP shocks or shocks to longer-term interest rates but invariant to shocks to the level and path of the federal funds rate, following Gurkaynak, Sack, and Wright (2007), I decompose the ten-year zero-coupon yield into a sequence of one-year forward rates. I show that monetary policy shocks (level and path) primarily influence forward rates at the short-to-medium end of the curve, with their explanatory power vanishing beyond the 7-year horizon. Conversely, auction-day surprises impact the forward curve across all maturities, with the greatest intensity at the long end. Consequently, I use the one-year forward rate from 9 to 10 years as the primary measure of long-term interest rates in my VAR analysis, as it is naturally insulated from conventional policy shifts.

Measuring longer term interest rates using the one-year forward, going from 9 to 10 years, I estimate a structural VAR model and identify shocks to longer term interest rates using the auction-day surprises on ten-year futures yields. A 10 basis point surprise easing in longer-term yields, mimicking shocks to balance sheet expansion or quantitative easing (QE) generates a more than proportionate decline in credit spreads and a sharp increase in monthly stock market returns. The decline in credit spreads translates to a persist decline in the unemployment rate with a trough response of around 20 basis points. Surprise easing of longer term rates is also inflationary in the medium to longer run, although the magnitude is smaller compared to the unemployment rate. A counterfactual exercise reveals that the borrowing cost channel – manifesting via changes in the credit spread – is the primary driver of these results; eliminating it wipes out nearly all the improvements in economic activity. The VAR model is linear and predicts symmetric

results for unforeseen tightening of longer term interest rates mimicking the effects of balance sheet normalization or quantitative tightening (QT).

To evaluate the contribution of episodes where the zero lower bound constraint on the federal funds rate is binding, I re-estimate the baseline specification by controlling for these episodes. While the results for most macroeconomic variables remain largely unchanged, inflation shows a stronger response. Extending the baseline sample from 2020/02 to 2023/12 allows us to capture the impact of the Fed's pandemic-era balance sheet easing. While the average effects are consistent across both samples, the estimated uncertainty around the macroeconomic impact is larger, perhaps because a vast array of fiscal and financial market interventions was also carried out during 2020 and 2021.

By exploiting the high-frequency structure of Treasury auctions, I isolate a measure of unforeseen changes in long-term yields that operates exclusively through the term premium, leaving risk-neutral expectations unchanged. This identification strategy, while rooted in daily auction dynamics, provides a scalable monthly proxy for the portfolio balance and duration channels —the primary transmission mechanism for Large Scale Asset Purchases (LSAPs). Unlike traditional event studies, which are limited to specific QE or QT episodes, this approach uses a broader sample to evaluate how shocks to the longer end of the ten-year forward curve propagate to slow-moving macroeconomic aggregates such as the unemployment rate and inflation.

The structural link rests on the fact that both demand shifts for ten-year Treasuries and Fed LSAPs target relevant long-term interest rates, orthogonal to the expected path of the federal funds rate, and affect the yield curve and other financial market variables in similar ways. By evaluating the macro impact of these mimicked demand shocks, I provide the empirical evidence currently missing in the literature: a statistically significant and economically relevant connection between balance sheet policy and real economic activity. These findings demonstrate that unforeseen shifts in the demand for long-term U.S. government debt—whether driven by exogenous changes in investor preferences or by central bank intervention—exert a potent and quantifiable influence on the broader economy.

Relation to existing studies: This article is broadly related to three strands of studies. The first group of studies examine the impact of auction-day surprises on financial markets. The identification is closest to Ray, Droste, and Gorodnichenko (2024), who document how unforeseen changes in Treasury yields around auctions quantify unforeseen changes in the demand for Treasuries. The analysis in Ray et al. (2024) also emphasize the scarcity channel stemming from the preferred habitat theory of Vayanos and Vila (2021). More broadly, this article is also related to studies that examine the dynamics between Treasury yields and the supply of government debt such as Greenwood and

Vayanos (2014), Phillot (2025). Krishnamurthy and Vissing-Jorgensen (2012) show that increases in the supply of Treasury operate mainly via changes in prices due to safety and liquidity concerns. Unforeseen changes in the demand for Treasuries on the other hand operate via changes in the term premium.

The second group of studies examine the impact of the Fed's balance sheet policies on financial markets. In an event study framework, Gagnon, Raskin, Remache, and Sack (2011) show that demand for Treasuries by the Fed through asset purchases reduces the supply of Treasuries held by private investors triggering a reduction in duration risk and lowering term premiums. Similarly, Krishnamurthy and Vissing-Jorgensen (2011) in an event study framework highlight the importance of the demand for safe assets, inflation and signaling channels. D'Amico and King (2013) using security-level data on Treasury prices and quantities shed light on the imperfect substitutability across assets stemming from preferred habitat investors. D'Amico, English, López-Salido, and Nelson (2012) also highlight the importance of the scarcity channel consistent with the preferred habitat theory and the duration channel. Swanson (2021) constructs a time-series of 'LSAP' shocks[1] using high-frequency identification around FOMC meetings and evaluates the impact on asset prices and interest rates as well.

The third group of studies estimate the impact of unconventional monetary policy on economic activity in the U.S. using high-frequency identification in a structural vector autoregression (VAR) model. The most closely related in this group are Miranda-Agrippino and Ricco (2023) and Swanson (2024). Swanson (2024) finds very weak evidence supporting the effectiveness of these policies in stimulating or restraining economic activity, while the findings in Miranda-Agrippino and Ricco (2023) are counterintuitive for LSAP policies. A disadvantage of these studies is that the sample used for identifying LSAP shocks begins in 2009. The identification and restricted sample size often deliver ambiguous evidence regarding the impact of quantitative easing and tightening on economic activity. Another point of distinction is the measure of longer-term interest rate. Instead of directly using the ten-year zero-coupon yield, I use the forward rate going from nine to ten years.

The rest of the article is organized as follows. Section 2 discusses the choice to focus on the yield of a ten-year zero-coupon Treasury security as a suitable measure of long-term interest rates. Section 3 describes the structure of U.S. Treasury Auctions and extracting surprises to the yields of ten-year T-Note futures around a thirty-minute window brack-

[1]Swanson (2021) extends the framework in Gurkaynak et al. (2005) to separately identify surprise changes in the federal funds rate, forward guidance, and large-scale asset purchases (LSAPs) for each FOMC announcement from July 1991 to June 2019. The LSAP factor measures surprise movements in the longer term interest rates with zero effects on federal funds rate and minimized to have zero impact on interest rates before 2009.

eting the closure of U.S. Treasury auctions. Section 4 discusses the high-frequency effect of unexpected variations in the demand for Treasuries on financial markets. Section 5 instruments shocks to long term interest rates using unforeseen changes in the demand for Treasuries on auction days to estimate the impact of the Fed's balance sheet policies. Section 5 also examines the robustness of results. Section 6 concludes.

2 Measure of long term interest rates

The U.S. government guarantees Treasury securities, which serve as a risk-free benchmark for various assets in financial markets, both within the U.S. and in the context of global financial markets. The ten-year Treasury security warrants special attention for the entire range of Treasury securities, as key borrowing costs for households and firms alike use the yield on the ten-year Treasury as the relevant risk-free rate. Therefore, changes in the ten-year yield directly impact household and firm activity via this link. Figure 1 illustrates this feature. Alongside playing a central role in financial markets as

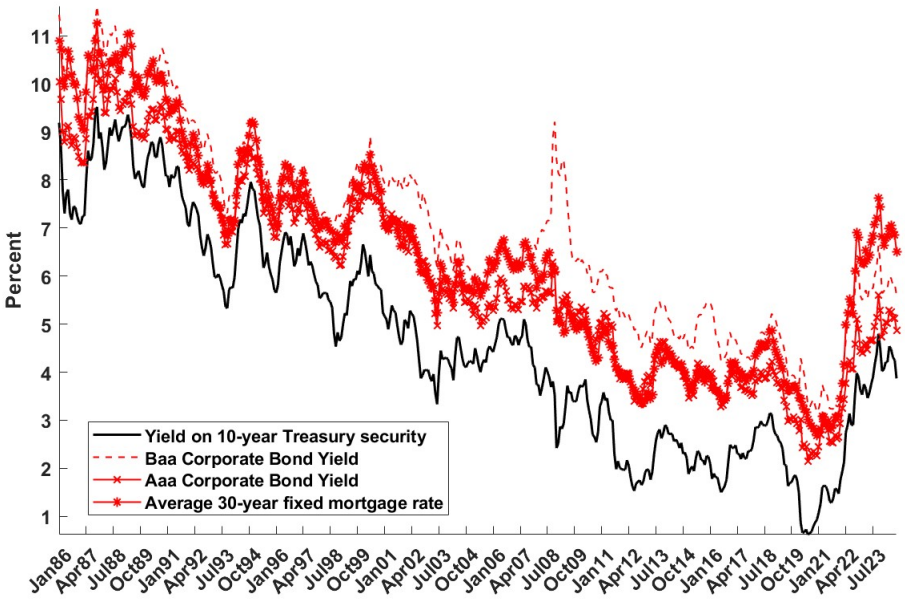


Figure 1: Borrowing costs in the economy for households as well as firms benchmarked to the yield on the ten-year Treasury security as the risk-free rate.

the benchmark risk-free rate, securities with maturity exceeding five years constituted the lion's share of the Treasury purchases during the Fed's LSAP programs. The first round of Large-Scale Asset Purchases (QE1), for instance, involved the purchase of $300 billion in longer-term Treasury securities, with maturities greater than five years accounting for about 50% of the volume (see Gagnon et al. (2011)), while the second round (QE2)

involved the purchase of $600 billion of longer-term Treasury securities. The ten-year Treasury is a good representative of assets purchased in various stages of LSAP implementation. Moreover, the effective duration of several longer-term assets purchased as part of the LSAP programs is closer to the ten-year benchmark. For instance, the duration on a 30-year MBS is around 7 years, more comparable to a ten-year Treasury (Krishnamurthy and Vissing-Jorgensen, 2011).

Most importantly, the market for ten-year T-Notes and futures is one of the most liquid globally, allowing accurate measurements of expectations about ten-year yields to be feasible. Therefore, in measuring longer-term interest rates that were central to the implementation of LSAPs, I focus exclusively on the ten-year zero-coupon Treasury security.

3 Treasury auctions and isolating unforeseen variations in ten-year Treasury yields

The U.S. federal government finances its operations primarily via collecting taxes and by selling securities of varying maturities, ranging from as short as four weeks to as long as thirty years via Treasury auctions. The schedule of auctions for Treasury securities is released at the Treasury's Quarterly Refunding press conference, usually held on the first Wednesday of February, May, August, and November.[2] Following the release of the schedule, each auction is preceded by an announcement sharing auction details, such as the offering amount available for auction, SOMA (System Open Market Account) Holdings Maturing, SOMA amounts included in the offering amount, and other relevant information. For example, for the ten-year security, initial offerings are announced in the first half of the month, with the auction day typically in the second week of the month. Auctions and auction announcements are usually separated by four to seven days. Press releases for the ten-year security types are available from August 5^{th}, 1998 onward; Figure 13 in Appendix 1 provides an example of a Treasury announcement on February 2nd, 2022 for an auction on February 9th 2022; and Figure 2 summarizes the frequency of U.S. Treasury auctions, and days between announcement and implementation dates.[3] Figure 2 shows 2009 onward Treasury auctions are held once every month.

Auctions allow for two types of bids – competitive and noncompetitive bids. An auction market participant can submit a competitive bid(s), with each bid specifying the minimum yield at which they are prepared to buy a specific quantity of notes. Alterna-

[2]See https://home.treasury.gov/policy-issues/financing-the-government/quarterly-refunding/most-recent-quarterly-refunding-documents for details.

[3]https://www.Treasurydirect.gov/auctions/announcements-data-results/announcement-results-press-releases/

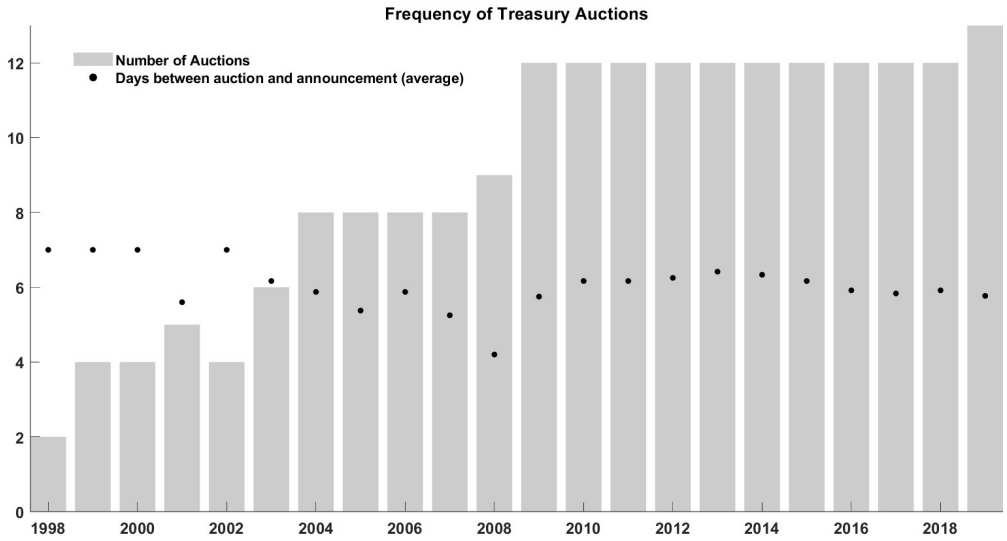


Figure 2: Documenting the frequency of U.S. Treasury auctions and average days between announcement and implementation of auctions for securities maturing in ten years. Since 2009, auctions have been scheduled every month. The figure excludes three additional auctions in 2008 for securities maturing in 6 years and 7 months (but classified as a ten-year security).

tively, they can also submit a noncompetitive bid specifying the amount of securities they wish to purchase at the price paid by successful competitive bidders. Noncompetitive bids are limited to $10 million, and bidding closes at 12.00 pm Eastern time.[4] Competitive bidding, on the other hand, is limited to a maximum of 35% of the offering amount and closes at 1.00 pm Eastern time.[5] Auction outcomes are determined as follows – the Treasury first accepts all the non-competitive bids consistent with the auction rules. Then, competitive bids are accepted based on their bid – yield, rate or discount margin – from lowest to highest, until the entire amount of the offering has been awarded. All successful bidders get the same rate, yield, or discount margin as the highest accepted bid.[6] The results are usually released on TreasuryDirect a few minutes after bidding closes. I allow for a thirty-minute window around auction closure to calculate the change in yields between 1.20 pm and 12.50 pm so as to allow markets sufficient time to react to the auction results. For most of the sample, each month has a single auction, in which cases, intra-day surprises and monthly surprises are interchangeable.

The market for ten-year Treasury notes and associated futures is among the most liquid financial markets globally (see Baker, McPhail, and Tuckman (2020)). Combined

[4]See https://www.treasurydirect.gov/marketable-securities/T-Notes/ for details.

[5]For more details see https://www.Treasurydirect.gov/auctions/announcements-data-results/announcement-results-press-releases/auction-results/,https://www.Treasurydirect.gov/auctions/how-auctions-work/.

[6]See https://treasurydirect.gov/auctions/how-auctions-work/ for details.

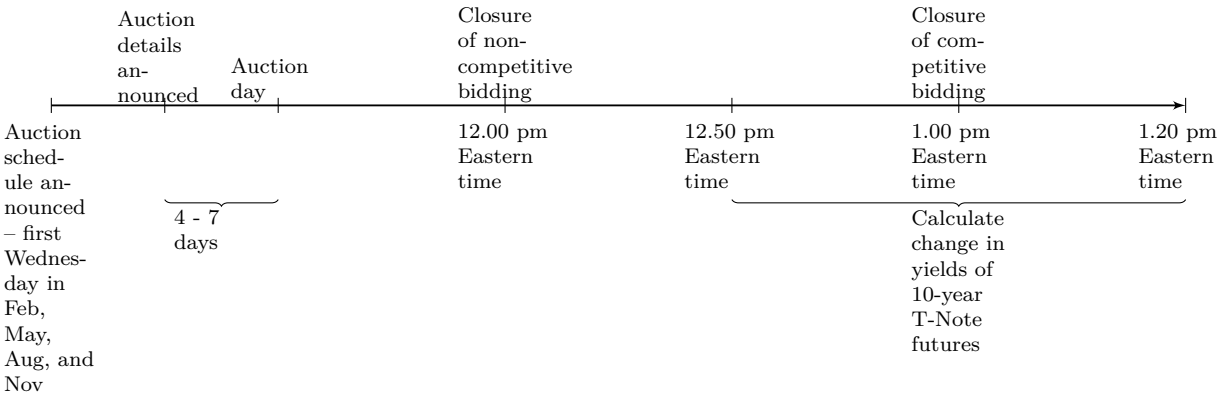


Figure 3: Timeline of auctions

with the fact that the futures contracts used to construct surprises to the ten-year Treasury yields expire at the end of the current quarter, movements in these ten-year Treasury futures yields adequately reflect market expectations about ten-year zero-coupon yields. With the total quantity of securities available for each auction fixed and sufficient time between the announcement of auction details and the implementation of auctions for participants to absorb information, it is unlikely that any other relevant news will be released within a 30-minute window bracketing the closure of auctions for the ten-year T-Notes. Movements in ten-year futures yields around that window thus capture unforeseen changes in market expectations about the demand for the ten-year T-Note security.

Auction day surprises - demand shocks for ten-year Treasuries I construct surprise movements in yields on ten-year T-Note futures by calculating the change around a thirty-minute window bracketing the closure of competitive bidding, using tick-level data between 12:50 pm and 1:20 pm Eastern Time on the days auctions are implemented. Table 1 reports summary statistics of changes in yields between 1.20 pm and 12.50 pm for both auction and non-auction days between 1998/08 and 2020/02. Table 1, among other differences, shows that the surprises vary more on auction days relative to non-auction days. Summary statistics contrasting auction and non-auction days are consistent with what Ray et al. (2024) report for the ten-year Treasury security using tick-level data from secondary market yields (including when-issued yields).

Changes in yields on auction days between 1.20 pm and 12.50 pm are then scaled by the standard deviation, such that a one-standard-deviation surprise equates to approximately a 1.7 basis point change in yields. Figure 4 plots this scaled series.

	Mean	Median	Standard Deviation	Minimum	Maximum	Number of observations
Non-Auction days	0.00	0.00	0.92	-6.95	5.93	4356
Auction days	-0.22	-0.10	1.71	-7.86	5.12	198

Table 1: Summary Statistics (basis points) of changes in yields underlying ten-year Treasury futures calculated between 1.20 pm and 12.50 pm Eastern time on auction and non-auction days between 1998/08 and 2020/02.

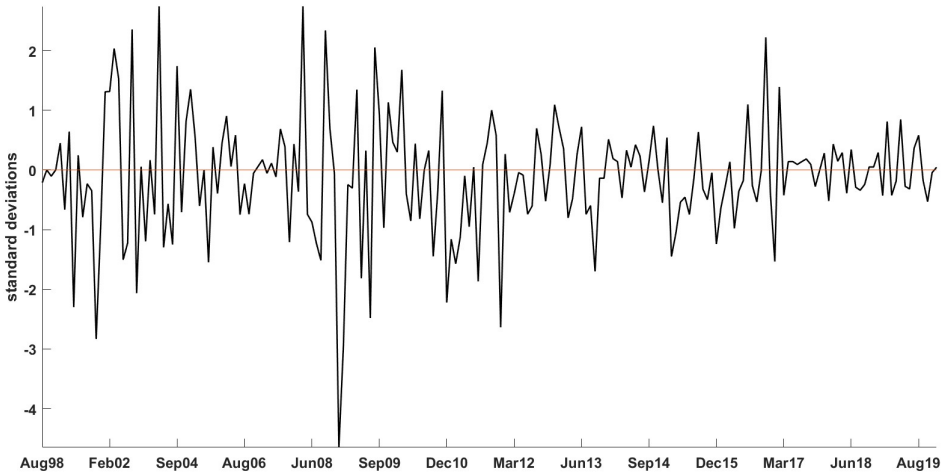


Figure 4: Surprises to yields on ten-year T-Note futures around a thirty-minute window bracketing the closure of U.S. Treasury auctions for ten-year securities. A one-standard-deviation surprise generates an increase in yields of about 1.7 basis points.

4 The effect of ten-year T-Note futures changes on asset prices

To measure the effects of surprises on the yields underlying ten-year T-Note futures on asset prices, I estimate the following regression, which has been frequently estimated in the literature examining the impact of high-frequency identification

$$\Delta y_t = \alpha_1 + \beta_1 Surprise_t + \epsilon_t^1, \tag{1}$$

with

$$\Delta y_t = y_t - y_{t-1}. \tag{2}$$

Here, $Surprise_t$ denotes the change in yield of the ten-year T-Note futures around a tight thirty window bracketing the closure of U.S. Treasury auctions of ten-year Treasury securities. Δy_t denotes the change in the yield of relevant assets (for example, one year Forward Rate going from nine to ten years). Δy_t is the difference between end-of-day yields on the day of the Treasury auction and the end-of-day yield on the day preceding the Treasury auction. If financial markets are closed the day preceding the auction, I use the end-of-day yield on the last day when markets are open before the auction to construct Δy_t. ϵ_t quantifies other shocks to asset prices outside of surprises to ten-year T-Note futures.

The assets I consider consist of the one-, five-, and ten-year zero-coupon Treasury securities, one-year forward rates going from one to two years, four to five years, and nine to ten years, and corporate bond yields – Moody's Aaa, Moody's Baa and the effective yield of the ICE BofA 7-10 Year US Corporate Index, respectively.[7] Zero-coupon Treasury yields and instantaneous forward rates are sourced from Gurkaynak, Sack, and Wright (2007) for zero-coupon Treasury securities. While the Moody's Seasoned Aaa and Baa Corporate Bond Yield measures the yield on corporate bonds that have the lowest default probability in the set of investment grade bonds, the ICE BofA 7-10 Year US Corporate Index, a subset of the ICE BofA US Corporate Master Index includes all dollar-denominated investment grade securities with a remaining term to maturity of greater than or equal to 7 years and less than 10 years.

Panels (a), (b) and (c) of Table 1 summarizes the estimated R^2 and F-statistics for the zero-coupon Treasury securities maturing in one, five, and ten years, one-year forward rates going from one to two, four to five, and nine to ten years, respectively, and corporate bond yields – Moody's AAA, Moody's BAA and the effective yield of the ICE BofA 7-10 Year US Corporate Index. Table 2 shows that auction day surprises impact these

[7] See FRED, Federal Reserve Bank of St. Louis https://fred.stlouisfed.org/series/DBAA, https://fred.stlouisfed.org/series/DBAA, https://fred.stlouisfed.org/series/BAMLC4A0C710YEY for details.

	Panel (a) - Zero-coupon Treasury yields		
Maturity	1 year	5 years	10 years
R^2	0.044	0.133	0.187
F-stat	9.16	30.32	45.64
	Panel (b) - Instantaneous forward rates		
Maturity	1 year	4 years	9 years
R^2	0.086	0.170	0.191
F-stat	18.66	40.68	46.70
	Panel (c) - Corporate Bond Yields		
	Moody's AAA Corporate Bond	Moody's BAA Corporate Bond	ICE BofA 7-10 Year US Corporate Index
R^2	0.125	0.15	0.188
F-stat	28.36	35.05	45.89

Table 2: Summarizing the impact of surprises to ten-year T-Note futures on zero-coupon yields, forward rates and corporate bond yields on auction days for ten-year Treasuries between 1998/08/14-2020/02/28. Surprises to ten-year T-Note futures have a stronger impact on yields at the medium to long run.

different interest rates across all horizons, Treasuries and corporate bond yields alike. The impact also increases with the maturity such that auction day surprises underlying ten-year T-Note futures yields have a bigger impact on assets whose maturity is close to ten years, explaining about 19% of daily variation in the ten-year zero-coupon yield, the 9-year instantaneous forward rate and the yield on corporate bonds maturing in seven to ten years respectively.

Preferred Habitat: To better understand the impact on interest rates across the maturity spectrum, I estimate equation (1) for zero-coupon Treasuries, with maturities between one and thirty years respectively. The explanatory power of surprises on ten-year T-Note futures, around a thirty-minute window bracketing the closure of Treasury auctions for ten-year securities, as Table 3 shows, increases monotonically until about 15 years in the maturity space. Yields are responsive at both the very short end and the very long end, but the impact is largely concentrated on securities closer to the ten-year maturity mark. Table 3 shows that surprises around auction closure to ten-year Treasuries generate effects consistent with the preferred habitat theory in Vayanos and Vila (2021).

Auction-day surprises for ten-year Treasuries between 1998/08/14-2020/02/28

	Zero-Coupon Treasury												
Maturity	1	2	3	4	5	6	7	8	9	10	15	20	30
β_1	0.007	0.013	0.016	0.019	0.021	0.022	0.024	0.025	0.025	0.026	0.025	0.023	0.016
t-stat	2.56	3.26	3.7	4	4.23	4.43	4.63	4.82	4.99	5.14	5.45	5.06	3.3
R^2	0.04	0.07	0.09	0.11	0.13	0.15	0.16	0.17	0.18	0.19	0.19	0.17	0.09
F-stat	9.16	15.9	20.71	25.58	30.32	34.65	38.37	41.41	43.82	45.64	47.61	41.34	19.36

Table 3: Effects across the maturity spectrum on auction days for ten-year Treasuries between 1998/08/14-2020/02/28. The first row, β denotes the estimated impact of a 1 standard deviation (1.7 basis points) change in the demand for Treasuries measured using changes in T-Note futures yields around a thirty-minute window bracketing auction closure in percent. The second row reports the t-statistic on the estimated coefficient. R^2 and F-stat denote the explanatory power and the significance of the estimated relation.

Transmission via the scarcity channel stemming from demand by preferred habitat investors is an important channel for shocks stemming from Large Scale Asset Purchases (LSAPs) by the Fed as well. To compare the impact of auction day surprises on the yield

curve with the impact of the Fed's large scale asset purchases, I estimate

$$\Delta y_t^j = \alpha_{2,j} + \beta_{2,j} LSAP_t + \epsilon_t^{2,j}. \tag{3}$$

with

$$\Delta y_t^j = y_t^j - y_{t-1}^j. \tag{4}$$

Here, $LSAP_t$ denotes the surprise changes underlying large scale asset purchases by the Fed as constructed in Swanson (2021) and Δy_t daily change in Treasury yields around FOMC announcements. Table 4 summarizes the findings. Consistent with the theoretical

LSAP surprises between 2009/01/01 and 2019/12/31 (Swanson, 2021)

	Zero-Coupon Treasury												
Maturity	1	2	3	4	5	6	7	8	9	10	15	20	30
β_2	0.007	0.02	0.034	0.045	0.053	0.058	0.061	0.062	0.062	0.061	0.052	0.043	0.035
t-stat	0.63	1.66	2.7	3.45	3.92	4.19	4.35	4.46	4.57	4.7	6.29	7.93	5.55
R^2	0	0.03	0.06	0.11	0.15	0.18	0.2	0.22	0.23	0.24	0.24	0.2	0.12
F-stat	0.9	6.33	16.42	28.45	40.42	51.13	60.02	66.95	71.98	75.33	73.74	58.58	32.8

Table 4: Effects across the maturity spectrum – LSAP shocks. The first row, β_2 denotes the estimated impact of a 1 standard deviation (5.4 basis points) LSAP shock as identified in Swanson (2021). The second row reports the t-statistic on the estimated coefficient. R^2 and F-stat denote the explanatory power and the significance of the estimated relation.

literature, LSAP shocks impact the yield curve across the maturity spectrum with the impact concentrated between 7-20 years in the maturity space. Moreover, qualitatively the findings in Tables 3 and 4 are consistent. LSAP shocks generate a larger effect quantitatively relative to auction day surprises – this stems from the fact that a one-standard deviation change in the factor quantifying LSAP shocks constructed in Swanson (2024) change the yield on the zero-coupon ten-year Treasury by 5.4 basis points (around 3.2 times the impact generated by auction day surprises.)

Duration channel: To understand what causes auction day surprises to impact longer term borrowing costs in the economy, I evaluate the impact of auction day surprises on risk-neutral yields and the term premium. Decomposing the ten-year Treasury yield into the risk-neutral yield and the term premium following Adrian, Crump, and Moench

(2013), I estimate

$$\Delta y_t^j = \alpha_{3,j} + \beta_{3,j} Surprise_t + \epsilon_t^{3,j}, \text{ where } j = tp, rny \tag{5}$$

with

$$\Delta y_t^j = y_t^j - y_{t-1}^j. \tag{6}$$

Here, Δy_t^{tp} (Δy_t^{rny}) denotes the daily change in term-premiums (risk-neutral yields) estimated by Adrian et al. (2013) around auction days for ten-year Treasuries. Panel (a) of Table 5 summarizes the total estimated impact of a one-standard deviation (1.7 basis points) change in yields of ten-year futures around a thirty-minute window bracketing auction closure. Panels (b) and (c) report the same for the term premium and the risk-neutral yields, respectively.

When decomposing the effects into risk-neutral yields and the term premium, Panel (b) of Table 5 shows that the explanatory power of surprises to ten-year T-Note futures around auction closure mainly operates through the term premium. The term premium accounts for almost 90% of the change in yields across the maturity spectrum. The component driven by risk-neutral yields is largely unresponsive to auction-day surprises. This results is intuitively consistent with the fact that Treasury auctions are not driven by shorter term business cycle fluctuations and the expected path of interest rates is pinned down by monetary policy under the guidance of the dual mandate. Thus, unforeseen variations in the demand for ten-year Treasuries along with preferred-habitat-like effects generates a reduction in term premium across the yield curve. Albeit larger changes in the term premium occur for longer-term Treasuries, even for the two-year Treasury risk premium changes by 1.1 basis points, and it is statistically significant.

In this way the impact of auction day surprises is consistent with the impact of LSAP shocks on yield curve via the 'duration channel' as outlined in Gagnon et al. (2011) and D'Amico, English, López-Salido, and Nelson (2012). LSAP purchases as intended by the Fed operate by lowering term premiums, and exerting a downward pressure on longer term interest rates, which spills over to important borrowing costs in the economy. To highlight this similarity, Table 6 decomposes the total impact of LSAP shocks into components driven by the term premium and the risk-neutral yield respectively. Barring the size of the effects, the impact on the term premiums cross the yield curve is consistent for auction day surprises and LSAP shocks.

4.1 Taking stock

The empirical evidence presented thus far establishes that unforeseen variations in the demand for ten-year Treasuries during auction windows possess significant explanatory

	Impact of surprises to ten-year futures around U.S. Treasury Auctions on Zero-Coupon Yields (%)									
Maturity	1	2	3	4	5	6	7	8	9	10
	Total Effect (%)									
β_1	0.007	0.012	0.016	0.019	0.021	0.022	0.024	0.025	0.025	0.026
t-stat	2.53	3.26	3.7	4	4.23	4.44	4.64	4.83	4.98	5.11
	Effect via the term premium (%)									
$\beta_{3,tp}$	0.006	0.011	0.014	0.016	0.018	0.019	0.021	0.022	0.022	0.023
t-stat	3.92	5.13	5.63	5.59	5.47	5.4	5.36	5.31	5.28	5.25
	Effects via risk-neutral yields (%)									
$\beta_{3,rny}$	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
t-stat	0.35	0.52	0.65	0.77	0.87	0.96	1.02	1.08	1.12	1.16

Table 5: Summarizing the impact of surprises to ten-year T-Note futures on zero-coupon yields, risk-neutral yields and term premiums. Surprises to ten-year T-Note futures constructed around a thirty-minute bracketing the closure of Treasury auctions largely impacts zero-coupon yields via the term premium component. The impact on risk-neutral yields across the maturity spectrum is negligible and statistically insignificant.

power across the entire yield curve. As the maturity of the underlying asset approaches the ten-year mark, the impact of these surprises increases symmetrically, providing strong empirical support for the Preferred Habitat Theory of Vayanos and Vila (2021). Crucially, this transmission to broader borrowing costs occurs primarily through the compression of the term premium, aligning with the Duration Channel identified by Gagnon et al. (2011) and D'Amico et al. (2012). By isolating unforeseen innovations in investor demand[8] within a high-frequency window, auction-day surprises serve a suitable instrument for identifying the effects of balance sheet policies, offering three distinct advantages over traditional event-study measures.

[8]While the Treasury's offering amount is fixed and pre-announced, the high-frequency price innovation at auction closure is driven by idiosyncratic variations in bidder appetite. Economically, a "negative demand surprise" is functionally equivalent to an expansion in the net supply of duration that the private sector must absorb, mirroring the mechanics of Quantitative Tightening.

Impact of LSAP shocks (Swanson, 2021) on Zero-Coupon Yields (%)										
Maturity	1	2	3	4	5	6	7	8	9	10
					Total Effect (%)					
β_1	0.006	0.02	0.035	0.046	0.053	0.058	0.06	0.062	0.063	0.063
t-stat	0.55	1.62	2.7	3.44	3.91	4.2	4.38	4.49	4.55	4.57
					Effect via the term premium (%)					
β_1	0.001	0.012	0.025	0.035	0.041	0.045	0.047	0.049	0.05	0.05
t-stat	0.22	2.24	4.19	5.28	5.69	5.77	5.69	5.55	5.38	5.21
					Effect via risk-neutral yields (%)					
β_1	0.005	0.007	0.01	0.011	0.012	0.013	0.013	0.013	0.013	0.013
t-stat	0.52	0.74	0.97	1.15	1.28	1.37	1.45	1.51	1.56	1.6

Table 6: Summarizing the impact of LSAP shocks (Swanson, 2021) on zero-coupon yields, risk-neutral yields and term premiums. LSAP shocks largely impact zero-coupon yields via the term premium component. The impact on risk-neutral yields across the maturity spectrum is negligible.

Transmission to Private Borrowing Costs: As shown in Table 2, these auction surprises not only affect yields on Treasuries with maturities around 10 years but also spill over significantly into corporate bond yields (Aaa, Baa, and the ICE BofA Index). The auction mechanism thus triggers the same broad financial tightening or easing that the Federal Reserve typically seeks through its LSAP programs.

Purity of the Duration Channel: As shown in Table 5, auction-day surprises operate almost exclusively ($\approx 90\%$) through the term premium, while risk-neutral yields remain statistically unresponsive. This isolation confirms that auctions provide a purer measure of the scarcity and duration channels, unaffected by the intended stance of the federal funds rate or shifting expectations of the Fed's dual mandate trajectory.

A High-Frequency Laboratory for Balance Sheet Expansion and Normalization: Treasury auctions are regular, maturity-specific, and frequent, allowing for an exclusive focus on the specific securities most sensitive to balance sheet policies. While the LSAP shocks identified in Swanson (2021) are constrained to the eight annual FOMC meetings, the auction cycle facilitates a granular mapping of yield curve responsiveness—demonstrated by the monotonic increase in explanatory power (R^2) peaking at the 10-to-15-year maturity mark, consistent with the Preferred Habitat Theory of Vayanos and Vila (2021). Furthermore, while identifying surprises around FOMC announcements using the third principal component is the standard extension of Gurkaynak et al. (2005), that approach involves estimation and identification challenges. In contrast, security-specific auction surprises provide a direct, high-frequency measure of how fluctuations in demand for duration impact market-clearing prices, mirroring the mechanism of central bank asset purchases.

Unforeseen changes in the demand for Treasuries can thus mimic shocks to the Fed's balance sheet policies – balance sheet expansion (quantitative easing) and balance sheet contraction (quantitative tightening). More generally, the effects examined via changes in the demand for Treasuries can be construed as the impact of unforeseen changes in longer-term interest rates.

5 Application: Impact of longer term interest rates to measure the impact of the Fed's balance sheet policies

Building on evidence that unforeseen variations in the demand for Treasuries effectively mimic the duration and scarcity channels of Federal Reserve balance sheet policies, I estimate the economic impact of the Fed's balance sheet policies using auction-day surprises in 10-year Treasury yields as the instrument. To carry out this analysis, however,

it is important to isolate a measure of long-term interest rates that is both representative of the asset classes targeted by LSAP programs and invariant to shorter-term monetary policy shocks to the level and path of the federal funds rate.

5.1 Decoupling Balance Sheet Policies from Conventional Monetary Policy

To isolate the variations in ten-year yields driven exclusively by shocks to longer-term interest rates—specifically those bracketing U.S. Treasury auction closures and independent of innovations to the level and path of the federal funds rate—I utilize a forward rate decomposition; following Gurkaynak, Sack, and Wright (2007), I express the yield on the ten-year zero-coupon security, $y_t(10)$, as the average of one-year continuously compounded forward rates:

$$y_t(10) = \frac{1}{10}\sum_{i=1}^{10} f_t(i,1). \tag{7}$$

$f_t(i,1)$ represents the one-year forward rate beginning i years into the future. This decomposition, derived in detail in Appendix 2, helps isolate the impact of shorter-term factors (related to cyclical fluctuations and monetary policy expectations) from longer-term factors (such as inflation and economic growth expectations) on the yield underlying the ten-year zero-coupon Treasury security.

As illustrated in Figure 5, shorter-term forward rates are heavily constrained by the factors determining the level and the path of the federal funds rate. When compared to the ten-year yield, the longer-dated forward rates thus focus more closely on the part of the yield curve that are most susceptible to shocks to longer-term interest rates via balance sheet policies.

To confirm this hypothesis and isolate a suitable measure of longer term interest rates, I utilize Equation (7) to identify which forward rate components are most sensitive to monetary policy shocks to the level and path of the of federal funds rate (MPS) identified around FOMC announcements versus demand-driven surprises around Treasury auctions for 10-year notes.

Specification 1 – Sensitivity to Treasury Auction Surprises First, I estimate the impact of surprises on ten-year T-Note futures bracketing Treasury auctions ($Surprise_t$) on the term structure of forward rates:

$$\Delta f_t(j,1) = \alpha_{4,j} + \beta_{4,j} Surprise_t + \epsilon_t^{4,j}, \quad \text{where } j \in 0,1,2,...,9. \tag{8}$$

with

$$\Delta f_t(j,1) = f_t(j,1) - f_{t-1}(j,1). \tag{9}$$

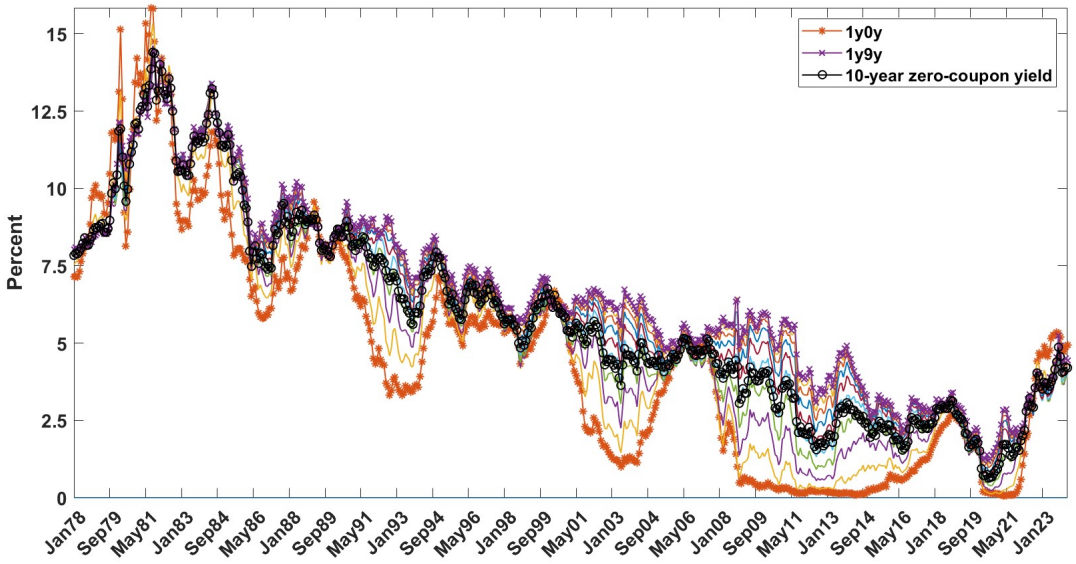


Figure 5: Decomposing the yield on the ten-year zero-coupon Treasury security into constituent forward rates distinguishing the influence of short-term, medium-term and longer-term factors.

$\Delta f_t(j,1)$ is the daily change in the one-year forward rate beginning in year j. $Surprise_t$ denotes the high-frequency change in ten-year T-Note futures yields around the thirty-minute window bracketing auction closure. Unlike the shocks to the level and path of the federal funds rate, centered on the front end of the curve, these surprises isolate the market's immediate reaction to changes in the net supply of long-term duration. These results, presented in Panel (a) of Table 2, serve as the baseline.

Specification 2 – Sensitivity to shocks to the level and path of the federal funds rate To contrast these findings with the impact of shocks to the level and path of the federal funds rate (MPS_t) on the term structure of forward rates, I estimate

$$\Delta f_t(j,1) = \alpha_{5,j} + \beta_{5,j} MPS_t + \epsilon_t^{5,j}, \quad \text{where } j \in 0,1,2,...,9 \tag{10}$$

Following the high-frequency identification literature—including Gurkaynak et al. (2005), Gertler and Karadi (2015), and Swanson (2021)—I define MPS_t using the measure developed by Bauer and Swanson (2023a). This instrument is constructed as the first principal component of changes in Treasury and Eurodollar futures within a thirty-minute window bracketing FOMC announcements, capturing surprises in both the current level and the expected path of the federal funds rate. To ensure identification reflects pure policy innovations, the measure is orthogonalized against non-monetary news, mitigating

potential 'Fed response to news' biases. The estimation results are reported in Panel (b) of Table 2.

	One-year Forward Rate									
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
	Panel (a) - Explanatory power of monetary policy shocks									
R^2	0.244	0.214	0.141	0.086	0.049	0.026	0.013	0.005	0.002	**0.0004**
F-stat	103.57	87.64	52.5	30.15	16.54	8.55	4.1	1.7	0.62	**0.14**
	Panel (b) - Explanatory power of surprises to ten-year futures on auction days (ten-year T-Notes)									
R^2	0.044	0.086	0.115	0.146	0.17	0.186	0.194	0.197	0.195	**0.190**
F-stat	9.16	18.7	25.74	33.86	40.55	45.16	47.73	48.5	48.09	**46.51**
	Panel (c) - Explanatory power of surprises to ten-year futures around U.S. Treasury Auction controlling overlapping and FOMC meeting days same month									
R^2	0.058	0.12	0.157	0.179	0.196	0.206	0.209	0.206	0.202	**0.197**
F-stat	6.06	13.42	18.36	21.47	23.99	25.55	25.97	25.61	24.93	**24.21**
	Panel (d): Explanatory power of surprises to ten-year futures on non-auction days (ten-year T-Notes)									
R^2	0.016	0.035	0.047	0.053	0.054	0.053	0.049	0.045	0.041	**0.0377**
F-stat	55.3	123.17	166.25	189.61	194.79	188.18	175.84	161.11	145.86	**132.78**

Table 7: R^2 and F-statistic: Disentangling the impact of monetary policy shocks and demand shocks for ten-year Treasuries on the components of the ten-year zero coupon security yield.

Table 7 shows that monetary policy shocks account for a significant portion of the variability underlying forward rates at the shorter end, with these effects becoming negligible for forward rates ranging from six to seven years and insignificant for forward rates extending from seven to eight years and beyond. Auction-day surprises, on the other hand, impact the shorter end of the yield curve, but the effects are quantitatively smaller, with the explanatory power increasing as we approach the longer end of the yield curve. The estimated impact on the forward rate going from nine to ten years has been highlighted in bold to compare these effects. Decomposing the ten-year zero-coupon yield curve into the constituent forward rates thus confirms that shocks to ten-year T-Note futures are relevant for the dynamics of the longer end of the yield curve. While monetary policy

shocks impact the ten-year zero-coupon security, they do so only for forward rates in the short and medium terms.

Specification 3: Controlling for FOMC meetings on the same month Specification 3 controls for all FOMC announcements overlapping with auction dates and those occurring in the same month as the auction for ten-year Treasury securities and I estimate

$$\Delta f_t(j,1) = \alpha_{6,j} + \beta_{6,j} Surprise_t + \gamma_1 d_{1,t} + \epsilon_t^{6,j}, \quad \text{where } j \in 0,1,2,...,9 \tag{11}$$

where $d_{1,t} = 1$ for all months having FOMC announcements, 0 otherwise. Panel (d) of Table 7 reports these results. Table 7 shows that the explanatory power across Specifications 5 and 6 is comparable to to what I estimate for the baseline scenario in equation (8).

Table 8 presenting detailed estimates of regression coefficients and R^2 for Specification 3 in Panel (c), shows that for longer-term forward rates, surprises in Treasury futures yields around auction closure generate quantitatively larger and significant movements relative to FOMC announcements in the same month. A one standard deviation positive surprise to ten-year yields around auction closure increases the forward rate going from nine to ten years by 3.2 basis points.

Specification 4 – Non-auction day surprises To verify that the identified effects are linked to the auction-day mechanism rather than intra-day volatility, I re-estimate Equation (8) using a placebo instrument ($Surprise_t^{NA}$). I construct this by calculating changes in ten-year T-Note futures yields within the same high-frequency window (12:50 PM to 1:20 PM ET) on days when no ten-year Treasury auction occurred.

$$\Delta f_t(j,1) = \alpha_{7,j} + \beta_{7,j} Surprise_t^{NA,j} + \epsilon_t^{7,j}, \quad \text{where } j \in 0,1,2,...,9. \tag{12}$$

where $\Delta f_t(i,1)$ represents the daily change in forward rates on these non-auction days, it is important to note that the control group of 'non-auction days' is defined specifically by the non-occurrence of a ten-year security issuance. However, it may include auctions for Treasury securities of other maturities. The results of this placebo test, reported in Panel (c) of Table 7, allow for a formal comparison between idiosyncratic market noise and the structural duration shocks identified during the primary auction windows.

Across these various specifications, the explanatory power of surprises to ten-year T-Note futures for longer-term forward rates is largely unchanged. The results in Table 7 and 10 suggests that forward rates at the longer end of the ten-year maturity spectrum, such as the forward rate going from nine to ten years, represent measures of long term

interest rates which are very responsive to shocks to the ten-year yield on auction days and simultaneously unaffected by monetary policy shocks. Table 8, summarizes the detailed regression coefficients estimated in equation (11). Table 10 in Appendix 4 summarizes the impact of auction-day surprises on the yield curve controlling for announcements related specifically to quantitative easing or tightening and FOMC announcements on the same day as the auction.

For completeness, to illustrate the impact on forward rate term premiums, I construct risk-neutral forward rates using and evaluate the forward rate term premium at each horizon, by subtracting the risk-neutral forward rates from market-implied forward rates, both constructed using equation (26) in Appendix 2. Table 9 in Appendix 3 reports the findings for risk-neutral forward rates and forward rate term premiums for auction and non-auction days. Table 9 reinforces the fact that the impact of shocks to longer term interest rates around auction closure operates via changes in term premiums. These

	One-year Forward Rate									
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
constant	-0.005	-0.015	-0.019	-0.017	-0.012	-0.008	-0.004	0	0.002	0.004
t-stat	-1.55	-2.61	-2.73	-2.29	-1.69	-1.06	-0.51	-0.06	0.27	0.52
β	0.007	0.016	0.022	0.026	0.028	0.029	0.031	0.031	0.032	**0.032**
t-stat	2.39	3.32	3.86	4.26	4.66	5	5.24	5.36	5.39	**5.38**
γ	0.01	0.025	0.029	0.028	0.025	0.021	0.018	0.016	0.014	**0.012**
t-stat	2.05	3.29	3.36	3.03	2.65	2.29	1.95	1.64	1.4	**1.21**
R^2	0.058	0.12	0.157	0.179	0.196	0.206	0.209	0.206	0.202	0.197
F-stat	6.06	13.42	18.36	21.47	23.99	25.55	25.97	25.61	24.93	24.21

Table 8: Detailed Regression Results, Specification 6 estimating $\Delta f_t(j,1) = \alpha_{6,j} + \beta_{6,j} Surprise_t + \gamma_1 d_{1,t} + \epsilon_t^{6,j}$, where $d_{1,t} = 1$ for FOMC announcements in the same month and 0 otherwise. The relative contribution of surprises to ten-year futures around the closure of Treasury auctions dominates FOMC announcements on the same month. A one-standard deviation change in $Surprise_t$ causes a 3.2 basis point change in longer-term forward rates (highlighted in bold). For short to medium forward rates FOMC announcements have significant and quantitatively comparable impact as longer term interest rate shocks measured by $Surprise_t$.

results suggest that if we go far out at the longer end of the forward rate yield curve underlying the ten-year zero coupon yield, we can isolate a measure of longer term interest rate that is unaffected by shocks to the level and path of the federal funds rate but sensitive to shocks driving longer term interest rates (orthogonal to the former). Hence, forward rates at the sufficiently long end of the forward rate yield curve underlying the relevant zero-coupon Treasury yield can be used as a policy instrument to quantify the impact of balance sheet policies or policies that are specifically stemming from changes in longer-term Treasury yields independent of shocks to the level and path of the federal funds rate.

5.2 Empirical Framework

I estimate a structural VAR model to evaluate the macroeconomic effects of shocks to balance sheet policies, mimicked by unforeseen demand for ten-year Treasuries as the instrument, using the forward rate from nine to ten years as the measure of longer-term interest rates. I estimate a reduced form VAR model such that

$$y_t = \alpha + B(L)y_{t-1} + u_t. \tag{13}$$

Here, y_t is the vector of endogenous variable where, $\dim(y_t) = n \times 1$. $B(L)$ is a polynomial in the lag operator and u_t is the vector of reduced form shocks with $Var(u_t) = \Omega$. I also assume that the system in equation (13) is invertible. Let ϵ_t be the vector of structural shocks such that $dim(\epsilon_t) = n$ and $Var(\epsilon_t) = \mathcal{I}$. Consistent with studies examining the effects of monetary policy shocks on the economy (see for instance, Gertler and Karadi (2015), Ramey (2016), Miranda-Agrippino and Ricco (2021), Bauer and Swanson (2023b), among others) I assume that the economy is driven by a set of n structural shocks, such that

$$u_t = S\epsilon_t; \text{ where } \dim(S) = n \times n \tag{14}$$

and one of these n structural shocks is the shock to the long-run interest rate ϵ_t^{LR}. Without loss of generality, let ϵ_t^{LR} be ordered first such that the first column of S describes the impact effects of shocks to long-term interest rates.

Data and Estimation I estimate equation (13) with vector of endogenous variables $y = [FR_{1,(9,10)}, \ln CPI, UR, GZ, \Delta S\&P, TB_1, TB_{10}, \pi^{10,e}]$. Here, $FR_{1,(9,10)}$ is the one-year forward rate going from 9 to 10 years, CPI is the Consumer Price Index, GZ is the Gilchrist and Zakrajšek credit spread (Gilchrist and Zakrajšek (2012)), UR is the unemployment rate, $\Delta S\&P$ is the monthly return on the Standard and Poor's 500 stock market index, TB_1 is the yield on the one-year Treasury security, TB_{10} is the yield on the

ten-year Treasury security. and π^e is 10-Year expected inflation calculated by the Federal Reserve Bank of Cleveland.[9] The sample for estimation begins 01/1982 since that is the earliest available data for the inflation expectations constructed by the Federal Bank of Cleveland. The CPI, unemployment rate , the credit spread and the return on the stock market are standard inclusions in VAR models studying the impact of monetary policy (see for instance, Gertler and Karadi (2015), Jarociński and Karadi (2020), Bauer and Swanson (2023b) among other others). The one-year zero-coupon yield captures the stance of monetary policy, including the impact of the zero lower bound on the federal funds rate. I also include 10-year expected inflation as it is an important determinant of longer term nominal yields. Equation (13) is estimated using monthly data between 01/1982 and 02/2020 using a lag length of 6.

The invertibility of the variance covariance matrix of the VAR coefficients and the sample covariance vector between the external instrument (z_t) and the reduced-form VAR residuals requires that $n^2p + \frac{n(n+1)}{2} + n$ is strictly less than T, where T denotes the total number of observations in the sample, p denotes lag-length in the VAR specification and n denotes the number of endogenous variables in y_t. The choice of lag-length is thus governed by this criteria. Nonetheless, a lag-length of 6 is consistent with Swanson (2024).

Shocks to longer-term interest rates, mimicking shocks via balance sheet policies are identified using data on unforeseen variation in ten-year T-Note futures yields around auction closure, controlling for FOMC announcements on the same day or month between 1998/08 and 2020/02.

High-frequency identification The identification of the impact of the shocks to balance sheet policies specifically on various dimensions of economic activity is achieved by using the external instrument approach. Here, movements in the yields of ten-year T-Note futures around a thirty-minute window bracketing the closure of U.S. Treasury auctions for ten-year Treasury notes, uncovering unforeseen variations in the demand for ten-year Treasuries and controlling for any FOMC announcement on the same day or same month of the auction, is the external instrument for shocks to longer term interest rates, measured by the one-year forward rate going from 9 to 10 years. Specifically, let, z_t denote the external instrument such that

$$Surprise_t = \alpha_0 + \beta_0 d_{1,t} + \epsilon_t^{\perp} \tag{15}$$

with

$$z_t = \epsilon_t^{\perp}. \tag{16}$$

[9]The data can be accessed via https://fred.stlouisfed.org/series/EXPINF10YR.

Using this definition, z_t should be such that

$$E(z_t \epsilon_t^{LR}) \neq 0 \tag{17}$$

and

$$E(z_t \epsilon_t^{j}) = 0 \; \forall j \neq LR. \tag{18}$$

This choice stems from the findings in Table 7 which shows that controlling for FOMC announcements on the same day or month as auctions for ten-year Treasury securities has the has the greatest explanatory power for daily variations in the one-year forward rate going from 9-10 years around auction closure.

The strength of instrument at a monthly level is evaluated by calculating the Wald statistic, ζ_1, for the covariance between the instrument and the normalized residual following Montiel Olea, Stock, and Watson (2021). The Wald statistic calculated using $y = [FR_{1,(9,10)}, \ln CPI, UR, GZ, \Delta S\&P, TB_1, TB_{10}, \pi^{10,e}]$ with data between 1982/01 and 2020/02 z_t as the external instrument, and estimated using 6 lags. Although the Wald statistic, $\zeta_1 = 8.4$, consistent with the findings in Montiel Olea, Stock, and Watson (2021) since as along as $\zeta_1 > \chi^2_{(1-0.05)} = 2.75$, the 90% Anderson-Rubin weak instrument confidence sets for impulse responses are bounded and valid inference can be conducted when identifying shocks to longer term interest rates mimicking shocks to balance sheet policies using the estimated results.

Exogeniety with respect to other structural shocks is achieved via the high-frequency identification technique as well as the fact the U.S. Treasury auctions are not driven by shorter term cyclical fluctuations. Exogeniety with respect to monetary policy shocks is achieved by using the forward rate going from nine to ten years as a measure of longer-term interest rate, consistent with the findings in Tables 7 and 10. Note that, there is nothing specific about the forward rate going from nine to ten years. A forward rate sufficiently far out in the maturity spectrum, which captures the dynamics of longer term rates and insensitive to shocks to the level and path of the federal funds rate should suffice.

5.3 Economic impact

I start by discussing the of a 10 basis point decrease in the longer end of the ten-year zero-coupon yield measured by the one-year forward rate going from 9 to 10 years. This exercise mimics the impact of a surprise balance sheet expansion. The VAR model in equation (13) is linear and the effects of a one-standard-deviation tightening is symmetric. Note, that the findings can also be interpreted to quantify the impact of unforeseen changes in the demand for Treasuries since the impact and higher-frequency transmission

for both experiments produce similar effects on long-term interest rates.

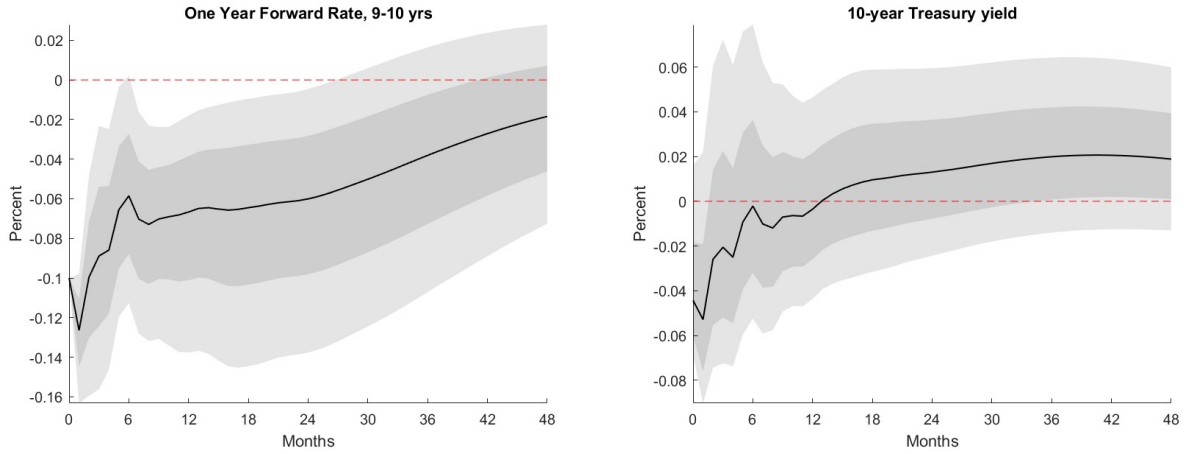


Figure 6: Impulse responses to a negative 10 basis point shock to the one-year forward rate going from 9 to 10 years for the one-year forward rate going from 9 to 10 years and the yield on ten-year zero-coupon Treasury security.Lighter (darker) shaded areas denote the 90% (68%) confidence bands (HAC).

A 10 basis point surprise easing causes an impact decline of 10 basis points in the one-year forward rate going from nine to ten years. Figures 6 - 9 plot the response of endogenous variables to this shock. On impact, the one-year forward rate, going from 9 to 10 years, declines with the impact of surprise easing persisting for several months. On the other hand, the response of the ten-year zero-coupon yield which meshes the impact of forward rates across the ten-year maturity spectrum, declines on impact but increases in subsequent periods and is statistically insignificant for the most part.

The credit spread, shows a sharp and significant decline on impact and this decline persists for up to 18 months after the shock. The more than proportionate decline in the credit spread in response to surprise easing is key as other papers exploring the impact of LSAPs fail to empirically establish this intuitive link (see, for instance, Swanson (2024), Miranda-Agrippino and Ricco (2023)). Along with the credit spread, the return on the S&P 500 increases sharply also.

The sharp decline in credit spreads is accompanied by a decrease in the unemployment rate on impact, and this decline is persistent hitting a trough around 18 months. Inflation decreases on impact and increases persistently thereafter. The increase is however, modest and significant only at a confidence level of 68%. Figure 7 plots these results. Figure 8 plots the responses of the 10-years ahead expected inflation and the 1-year Treasury yield. In response to a surprise easing of longer-run interest rates, 10-years ahead inflation expectations over the improve on impact and this persists for several months after the shock. Although, similar to the response of CPI-inflation, this increase is significant only

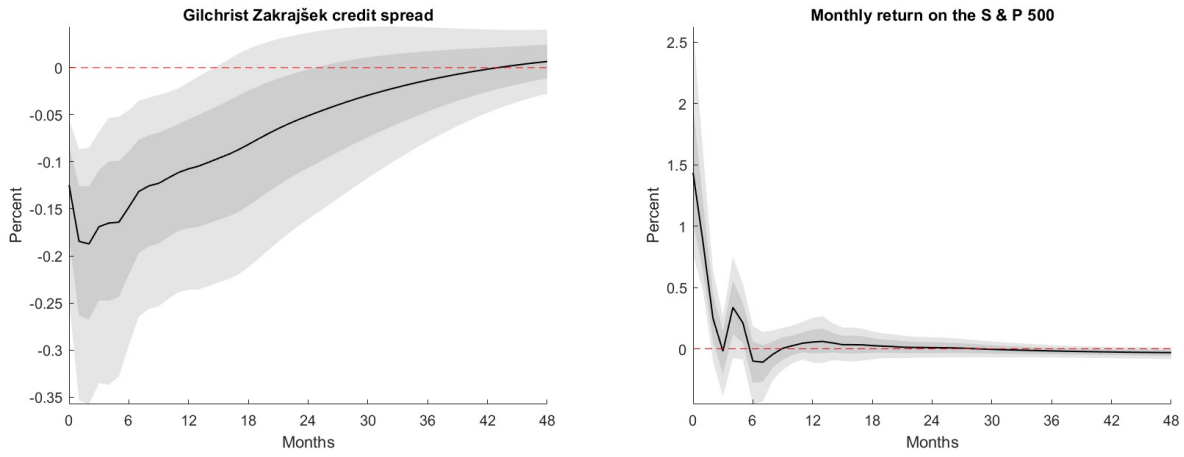


Figure 7: Impulse responses of the Gilchrist and Zakrajšek credit spread and the log of the S&P 500 to a negative 10 basis point shock to the one-year forward rate going from 9 to 10 years. Identification and estimation include the Great Recession. Shock identified using data between 1998/08 and 2020/02. Lighter (darker) shaded areas denote the 90% (68%) confidence bands (HAC).

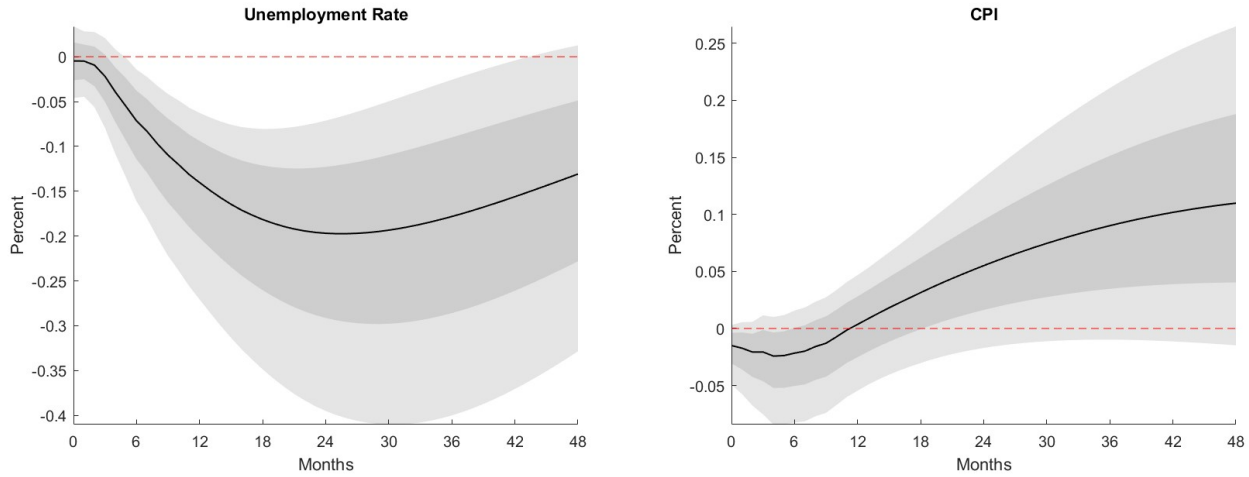


Figure 8: Impulse responses of the unemployment rate and the log of the CPI to a negative 10 basis point shock to the one-year forward rate going from 9 to 10 years. Shock identified using data between 1998/08 and 2020/02. Lighter (darker) shaded areas denote the 90% (68%) confidence bands (HAC).

at a confidence level of 68%. Finally, as the improvement in economic conditions gains strength, the one-year yield increases, but modestly in comparison to the decrease in the unemployment rate.

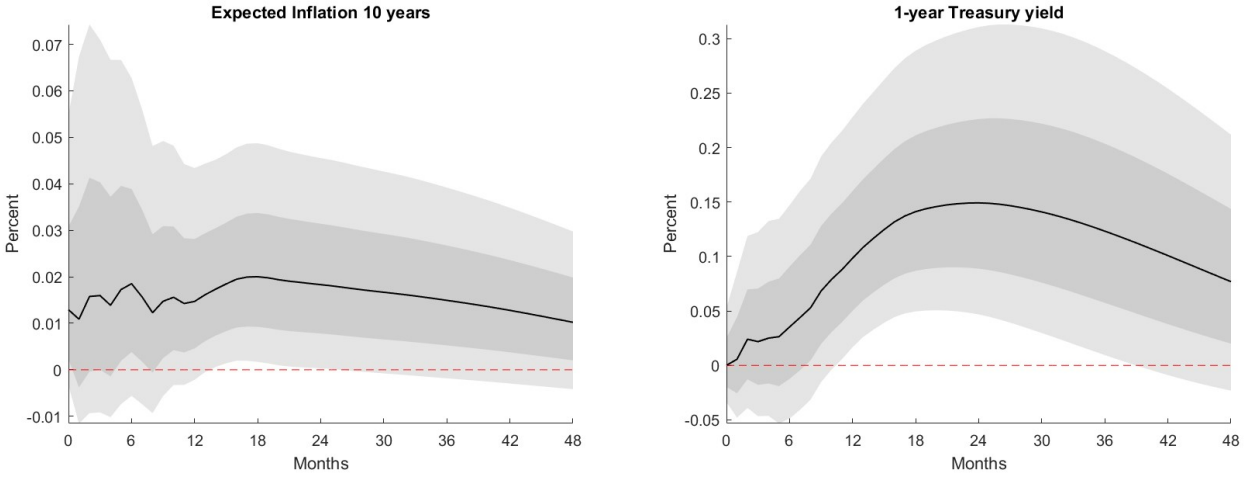


Figure 9: Impulse responses of the 10-year inflation expectations and the 1-year Treasury yield to the one-year forward rate going from 9 to 10 years. Shock identified using data between 1998/08 and 2020/02. Lighter (darker) shaded areas denote the 90% (68%) confidence bands (HAC).

Transmission Mechanism To highlight the importance of the borrowing cost channel of transmission underlying balance sheet policies, I conduct a counterfactual exercise. I estimate equation (13) as before, but when constructing impulse responses, I set the response of the credit spread to zero. Figure 10 plots the impulse responses of this counterfactual exercise along with the results in Figures 6 - 9. Figure 10 shows that when the borrowing cost channel is switched off, easing of longer-term interest rates no longer generates the significant improvement in economic activity as seen in Figures 6 - 10. Industrial production shows a persistent decline. The unemployment rate declines; however, it is significantly smaller than the baseline. The stock market improves, but the improvement is less persistent. Figure 10 shows that the increase in the stock market is in part driven by the sharp decline in credit spreads, which triggers a decline in total borrowing costs and spills over to improved stock market performance.

Figures 6 - 10 consider an unforeseen balance sheet expansion by a 2 basis point easing of longer term interest rates. When scaled appropriately, a 10-basis-point reduction in long-term interest rates, measured using the forward rate from nine to ten years, generates a peak response in industrial production of 38 basis points and a trough response in the unemployment rate and the credit spread of 22 basis points and 28 basis points,

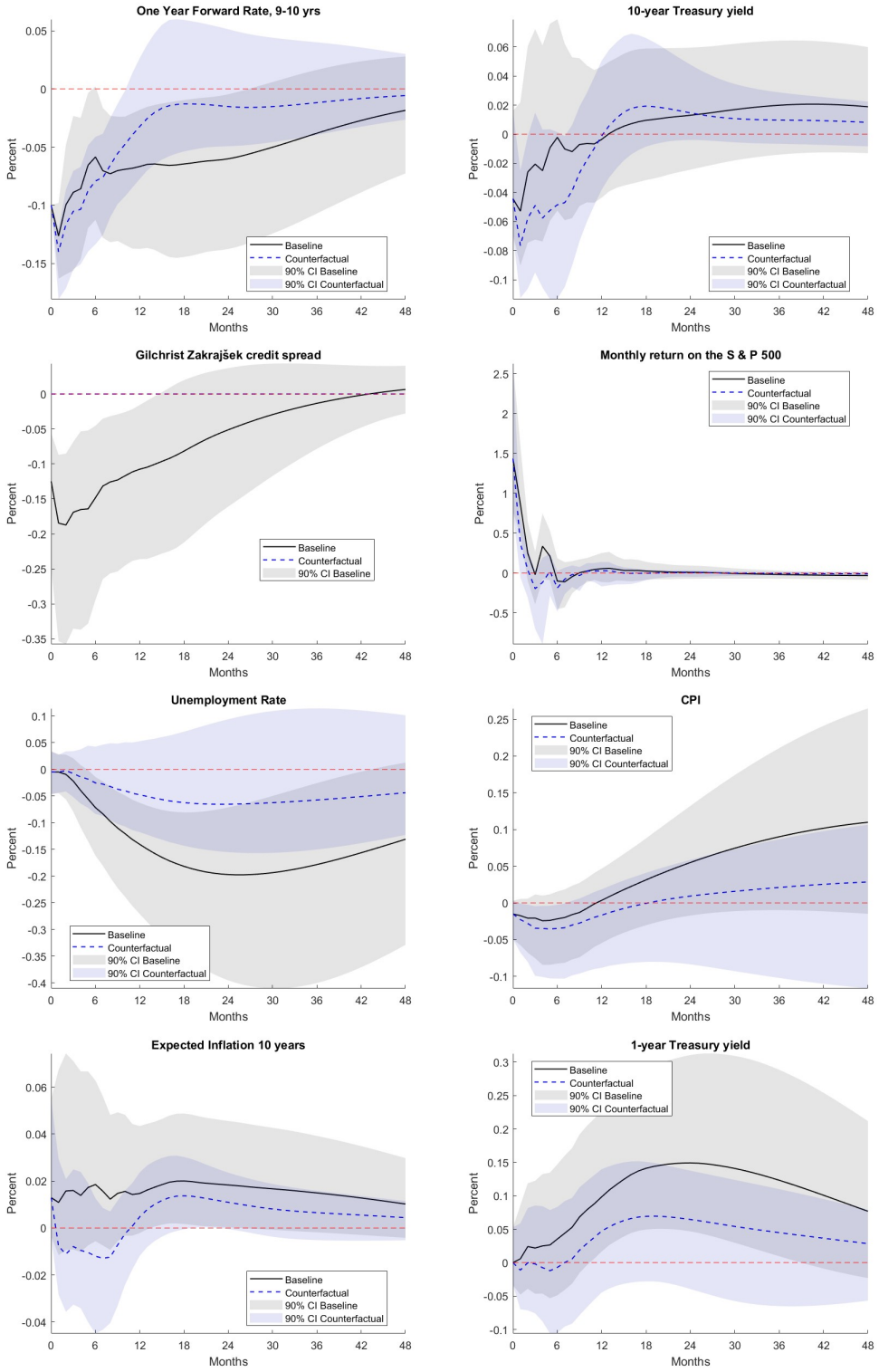


Figure 10: Counterfactual analysis – switching off the response of the credit spread: Impulse responses of the 1-year forward rate, going from 9 to 10 years, the 10-year Treasury yield, the unemployment rate, log of the CPI, the credit spread, monthly return on the S&P 500, 10-years ahead expected inflation, and the one year Treasury yield to a negative 10 basis point shock to one-year forward rate going from 9 to 10 years. Light shaded areas denote the 90% confidence intervals.

respectively.

5.4 Controlling for the Zero Lower Bound

The VAR model in equation (13) is linear and predicts symmetric results for expansionary and contractionary shocks to longer term interest rates. Consequently, the impact of quantitative easing (QE) and quantitative tightening (QT) are symmetric when these shocks mimic balance sheet expansion and normalization. Given the restriction on the number of parameters and the total number of observations, I control for the zero lower bound (ZLB) on nominal interest rates by augmenting equation (13) with an exogenous regressor that takes the value 1, when the ZLB constraint binds and 0 otherwise such that

$$y_t = \alpha + B(L)y_{t-1} + CW_t + u_t, \tag{19}$$

where $W_t = 1$ if $t \in (2009/01, 2015/11)$ and 0 otherwise. Figure 11 compares impulse responses estimated following equation (19) with the baseline specification in equation (13).

The impulse responses of endogenous variables, controlling for the ZLB on nominal interest rates, is largely unchanged with the exception of inflation and inflation expectations. Both variables now show a stronger response over the medium to long run compared to the baseline.

5.5 Extended Sample

The data in the main analysis stops at 2020/20 prior to the incidence of the covid-19 pandemic, primarily to eliminate the influence various large scale fiscal and monetary interventions undertaken to mitigate the impact of the pandemic. As a robustness check, I re-estimate equation (13) using data between 1982/01 and 2023/12. Figure 12 compares these results with the baseline sample.

The findings for the extended sample are qualitatively consistent with what I estimate for the sample ending 2020/02 and the mean effects largely comparable across all variables. The estimated uncertainty around the mean responses is however greater for the extended sample. This could be due to various large scale fiscal and credit programs extended during the pandemic which are unaccounted for in the analysis.

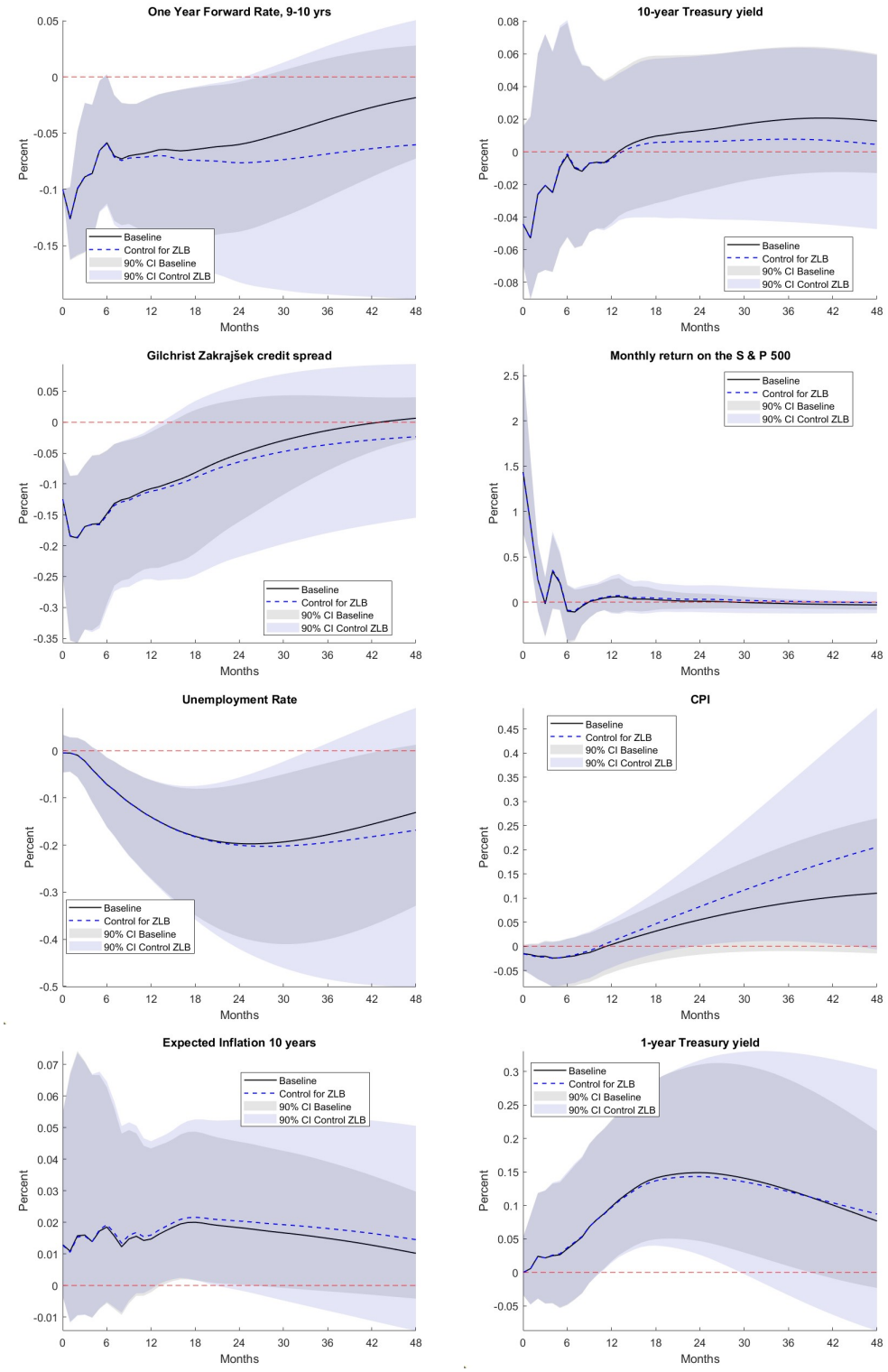


Figure 11: Controlling for the ZLB: Impulse responses of the 1-year forward rate, going from 9 to 10 years, the 10-year Treasury yield, the unemployment rate, log of the CPI, the credit spread, monthly return on the S&P 500, 10-years ahead expected inflation, and the one year Treasury yield to a negative 10 basis point shock to one-year forward rate going from 9 to 10 years. Shaded areas denote the 90% confidence intervals.

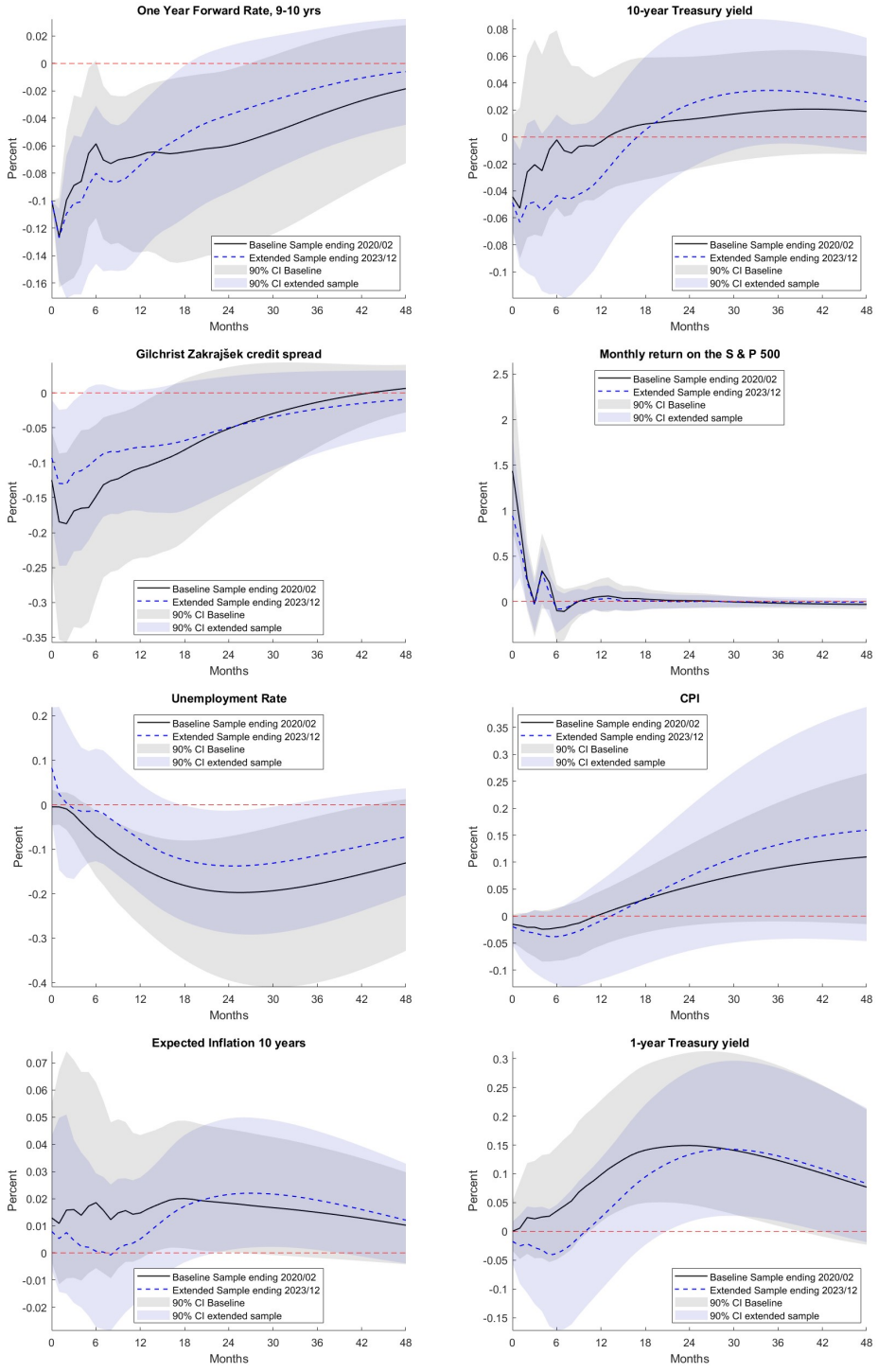


Figure 12: Extended sample: Impulse responses of the 1-year forward rate, going from 9 to 10 years, the 10-year Treasury yield, the unemployment rate, log of the CPI, the credit spread, monthly return on the S&P 500, 10-years ahead expected inflation, and the one year Treasury yield to a negative 10 basis point shock to one-year forward rate going from 9 to 10 years. Solid black line plots results for the baseline analysis – VAR coefficients and residuals estimated using data between 1982/01 and 2020/02 and 1998/08 and 2020/02, respectively. Dashed blue line plots results for the baseline analysis – VAR coefficients and residuals estimated using data between 1982/01 and 2023/12 and 1998/08 and 2023/12, respectively. Shaded areas denote the 90% confidence intervals.

6 Conclusion

An unforeseen increase in demand for ten-year Treasuries leads to a decline in longer-term yields clustered around the 10-year benchmark. Exogenous changes in the demand for Treasuries also spill over to important borrowing costs in the economy, such as the AAA and BAA corporate bond spreads, operating via changes in the term premium. Shocks to longer-term interest rates measured using high-frequency changes in ten-year futures yields thus mimic the properties of unforeseen changes in the size of the Fed's balance sheet.

Using auction-day changes in the ten-year futures as the instrument, I empirically quantify the impact of unforeseen changes in longer-term interest rates on the macroeconomy. The empirical results demonstrate that a surprise decline in longer-term Treasury yields – the risk-free rate for important interest rates in the U.S. economy and in global financial markets – leads to a more-than-proportionate decline in credit spreads and a persistent decline in the unemployment rate. The natural structure of Treasury auctions thus allows us to measure the effects of the Fed's balance sheet policies on macroeconomic activity. Previous work, while successfully demonstrating the effectiveness of balance sheet policies on financial markets at intra-day or daily frequencies, has been unable to credibly quantify their impact on economic variables of interest. The findings thus inform us about the potency of longer-term interest rates as a policy tool independent of the usual policy instruments.

With balance policies becoming a key ingredient in the central banking toolkit, the results can suitably inform the conduct of policy in turbulent times when the Fed has fully utilized the federal funds rate and forward guidance.

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Appendix

1 Auction announcement by the Treasury

TREASURY NEWS

Department of the Treasury • Bureau of the Fiscal Service

Embargoed Until 08:30 A.M.
February 02, 2022

CONTACT: Treasury Auctions
202-504-3550

TREASURY OFFERING ANNOUNCEMENT [1]

Term and Type of Security	10-Year Note
Offering Amount	$37,000,000,000
Currently Outstanding	$0
CUSIP Number	91282CDY4
Auction Date	February 09, 2022
Original Issue Date	February 15, 2022
Issue Date	February 15, 2022
Maturity Date	February 15, 2032
Dated Date	February 15, 2022
Series	B-2032
Yield	Determined at Auction
Interest Rate	Determined at Auction
Interest Payment Dates	August 15 and February 15
Accrued Interest from 02/15/2022 to 02/15/2022	None
Premium or Discount	Determined at Auction
Minimum Amount Required for STRIPS	$100
Corpus CUSIP Number	912821HJ7
Additional TINT(s) Due Date(s) and	None
CUSIP Number(s)	None
Maximum Award	$12,950,000,000
Maximum Recognized Bid at a Single Yield	$12,950,000,000
NLP Reporting Threshold	$12,950,000,000
NLP Exclusion Amount	$0
Minimum Bid Amount and Multiples	$100
Competitive Bid Yield Increments [2]	0.001%
Maximum Noncompetitive Award	$5,000,000
Eligible for Holding in TreasuryDirect ®	Yes
Estimated Amount of Maturing Coupon Securities Held by the Public	$54,805,000,000
Maturing Date	February 15, 2022
SOMA Holdings Maturing	$66,546,000,000
SOMA Amounts Included in Offering Amount	No
FIMA Amounts Included in Offering Amount [3]	Yes
Noncompetitive Closing Time	12:00 Noon ET
Competitive Closing Time	1:00 p.m. ET

[1] Governed by the Terms and Conditions set forth in The Uniform Offering Circular for the Sale and Issue of Marketable Book-Entry Treasury Bills, Notes, and Bonds (31 CFR Part 356, as amended), and this offering announcement.

[2] Must be expressed as a yield with three decimals e.g., 7.123%.

[3] FIMA up to $1,000 million in noncompetitive bids from Foreign and International Monetary Authority not to exceed $100 million per account.

Figure 13

2 Deriving forward rates

Following the notation in Gurkaynak, Sack, and Wright (2007), if $d_t(n)$ is the discount function, then the continuously compounded yield, $y_t(n)$ on an n-period zero-coupon bond is given by

$$y_t(n) = -ln(d_t(n))/n \tag{20}$$

and the yield on a n-by-m forward rate is given by

$$f_t(n,m) = -\frac{1}{m}\ln\frac{d_t(n+m)}{d_t(n)} = \frac{1}{m}[(n+m)y_t(n+m) - ny_t(n)] \tag{21}$$

Taking the limit of equation (21) as $m \to 0$, gives us the instantaneous forward rate, $f_t(n,0)$, n years ahead, which represents the instantaneous return for a future date (n years hence) which an investor demands today with

$$f_t(n,0) = y_t(n) + ny_t'(n). \tag{22}$$

Using equation (22), an investment today can therefore expressed as sum of forward rate agreements over the the horizon of the investment, with the yield equaling the average of the sequence of those forward rates.

$$y_t(n) = \frac{1}{n}\int_o^n f_t(x,0)dx \tag{23}$$

In discrete time, the n-period zero coupon yield on a security can be expressed as an average of one-year continuously compounded forward rates such that

$$y_t(n) = \frac{1}{n}\sum_{i=0}^{n-1} f_t(i,1) \tag{24}$$

Therefore for a zero-coupon security maturing in 10 years,

$$y_t(10) = \frac{1}{10}\sum_{i=0}^{n-1} f_t(i,1) \tag{25}$$

where $f_t(i,1)\ \forall i \in [0,9]$ is the one-year continuously compounded (i)-by-1 forward rate. Using equation (25), forward rates can be calculated as

$$f_t(i,1) = (i+1)y_t(i+1) - (i)y_t(i)\ \forall i \in [0,9] \tag{26}$$

3 Impact on forward rates

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Panel (a) - Impact of surprises to ten-year futures around U.S. Treasury Auctions - One-year Forward Rates - Total Effect (%)										
R^2	0.007	0.016	0.022	0.026	0.028	0.029	0.031	0.031	0.032	0.032
F-stat	2.39	3.32	3.86	4.26	4.66	5	5.24	5.36	5.39	5.38
Panel (b) - Impact of surprises to ten-year futures around U.S. Treasury Auctions - Term premium										
R^2	0.006	0.015	0.02	0.023	0.025	0.026	0.027	0.028	0.029	0.03
F-stat	3.93	5.49	5.29	4.96	4.95	5.02	5.03	5.01	4.99	4.97
Panel (c) - Impact of surprises to ten-year futures around U.S. Treasury Auctions - Risk-Neutral Zero-Coupon Yields (%)										
R^2	0.001	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003
F-stat	0.24	0.41	0.64	0.86	1.04	1.18	1.28	1.35	1.39	1.43

Table 9: Summarizing the impact of surprises to ten-year T-Note futures on one-year forward rates, one-year risk-neutral forward rates implied yields and one-year forward rate term premiums.

4 Disentangling impact attributed to FOMC announcements on the same day as Treasury auctions

Specification 5: Disentangling impact attributed to QE/QT announcements on same days as auctions

Next, I check if the effects attributed to surprises on the yields of ten-year T-Note futures might be driven by those QE/QT news releases/announcements. Between 1998/08 and 2019/12, there are seven dates on which U.S. Treasury auctions for ten-year securities overlap with FOMC announcements. The overlapping FOMC announcements not only include the QE/QT related monetary policy shocks but also shocks to the level and path of the federal funds rate that might have occurred on those days. These dates are as follows 6/11/2002, 10/11/2004, 8/10/2008, 12/08/2009, 13/12/2011, 13/03/2012, 12/12/2012. To account for this overlap, when I regress forward yields on estimated surprises to ten-year T-Note futures around auctions, I drop for these dates from the estimation.

$$\Delta f_t(j,1) = \alpha_{7,j} + \beta_{7,j} Surprise_t + \epsilon_t^{7,j}, \quad \text{where } j \in 0,1,2,...,9 \tag{27}$$

Table 10 below compares the estimates from equation (10) with estimates from equation (27). After dropping for these dates overlapping with auctions, the explanatory power of the proposed instrument decreases; however, the explanatory power of shocks to ten-year T-Note futures remains relevant even after. Panel (b) of Table 10 reports these results.

Specification 6: Instead of dropping overlapping FOMC dates, the next specification controls for these dates with

$$\Delta f_t(j,1) = \alpha_{8,j} + \beta_{8,j} Surprise_t + \gamma_2 d_{2t} + \epsilon_t^{8,j}, \quad \text{where } j \in 0,1,2,...,9 \tag{28}$$

where $d_{2t} = 1$ for each of these 7 dates, 0 otherwise.Panel (c) of Table 10 reports these results. Controlling for these dates overlapping with auctions, compared to Specification 1, the R^2 statistic increases but only by a small amount (1%); Panel (c) of Table 10 reports these results.

	One-year Forward Rate									
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
	Panel (a) - Explanatory power of surprises to ten-year futures around U.S. Treasury Auctions									
R^2	0.044	0.086	0.115	0.146	0.17	0.186	0.194	0.197	0.195	**0.19**
F-stat	9.16	18.7	25.74	33.86	40.55	45.16	47.73	48.5	48.09	**46.51**
	Panel (b) - Explanatory power of surprises to ten-year futures around U.S. Treasury Auctions **dropping overlapping FOMC meeting days**									
R^2	0.032	0.086	0.104	0.124	0.139	0.148	0.152	0.152	0.151	**0.149**
F-stat	6.37	17.86	22.19	27	30.73	33.08	34.14	34.31	34.01	**33.37**
	Panel (c) - Explanatory power of surprises to ten-year futures around U.S. Treasury Auctions **controlling overlapping FOMC meeting days**									
R^2	0.056	0.114	0.146	0.177	0.199	0.212	0.217	0.215	0.209	**0.201**
F-stat	5.79	12.63	16.86	21.23	24.53	26.55	27.29	26.97	26.09	**24.75**
	Panel (d) - Explanatory power of surprises to ten-year futures around U.S. Treasury Auction **controlling FOMC meeting days same month**									
R^2	0.058	0.12	0.157	0.179	0.196	0.206	0.209	0.206	0.202	0.197
F-stat	6.06	13.42	18.36	21.47	23.99	25.55	25.97	25.61	24.93	24.21

Table 10: R^2 and F-statistic of the regression of forward rates on the instrument capturing surprises to the ten-year Treasury futures yields across Specifications 2,4,5 and 6 respectively. Controlling for FOMC announcements on the same day and same month as auctions does not change the explanatory power significantly relative to the baseline specification (Panel (a)). Even if overlapping FOMC dates are dropped, surprises around a thirty-minute window bracketing the closure of Treasury auction for ten-year T-Note securities have sufficient explanatory power.