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ABSTRACT

The sensitivity of long-term rates to short-term rates represents a puzzle for standard macro-finance models. Post-FOMC announcement drift in Treasury markets after Fed Funds target changes contributes to the excess sensitivity of long rates. Mutual fund investors respond to the salience of Fed Funds target rate increases by selling short and intermediate duration bond funds, thus gradually increasing the effective supply to be absorbed by arbitrageurs. Using FOMC-induced variation in bond fund flows, we estimate short-run demand for Treasurys to be inelastic, especially for longer maturities. The gradual increase in supply, combined with the low demand elasticity, generate post-announcement drift in Treasurys, which spills over to other bond markets. Our findings shed new light on the causes of time-series-momentum in Treasury markets.

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A data appendix is available at http://www.nber.org/data-appendix/w25127

1 Introduction

Long-term nominal and real rates co-vary strongly with short-term rates (Cochrane and Piazzesi, 2002; Gürkaynak, Sack, and Swanson, 2005a; Hanson and Stein, 2015; Hanson, Lucca, and Wright, 2017). Gürkaynak, Sack, and Swanson (2005a) call this the excess sensitivity of long rates, and this represents a challenge to standard macro-finance models. The standard model predicts that higher short-term interest rates lower long-term inflation expectations and leave long-term real interest rates largely unchanged, thus lowering long-term nominal rates. In U.S. data, innovations to inflation expectations explain only a small fraction of the variation in longer maturity Treasury yields (Nakamura and Steinsson, 2018; Duffee, 2018).

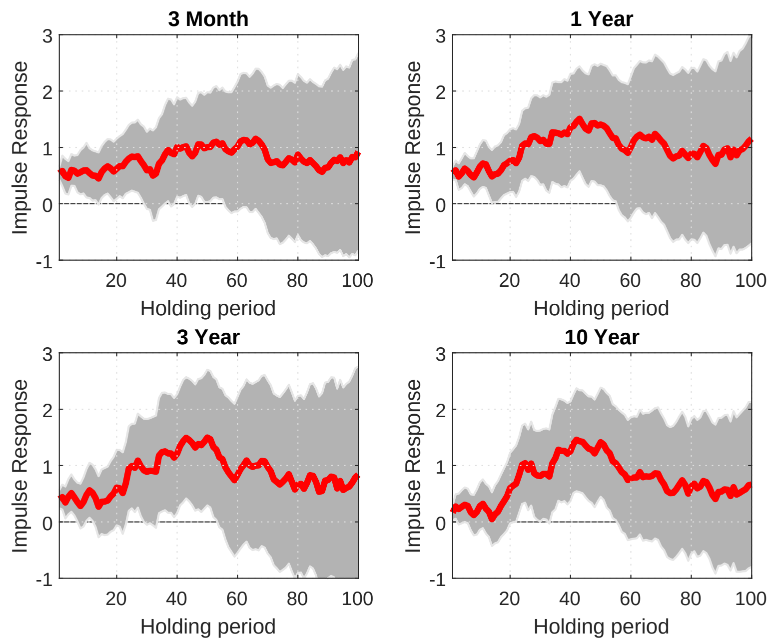
Our paper demonstrates that there is post-FOMC announcement drift in bond markets, which contributes to and deepens the puzzling relation between short and long rates. Figure 1 plots the response of Treasury yields to surprises in the Federal Funds rate. Treasury yields at longer maturities initially respond sluggishly to Fed Funds rate surprises. The same-day response of 10-year Treasury yields to a 10 bps. surprise in the Fed Funds rate is only 1.7 bps, but, after 50 days, yields on 10-year Treasurys have increased by 14 bps. After 50 days, the yields on long-term Treasurys partially revert back. The over-reaction in Treasury markets is wholly attributable to FOMC meeting days on which the Fed Funds target rate was changed. As a result, long-term yields are even more sensitive to short rates than you think.

FOMC announcement days provide us with a natural asset pricing experiment to test the expectations hypothesis. Only news about the short rate is released. We can control for news about the path of interest rates. The surprise is orthogonal to current and future fundamentals, except when the Fed has private information about the macro-economy. As a result, risk premia on Treasurys should be invariant in response to this news. However, there is recent evidence that investors do revise their expectations about future fundamentals (Nakamura and Steinsson, 2018) in response to monetary surprises, which could feed back into bond risk premia. We control for these effects.[1]

The expectations hypothesis seems to hold on FOMC meeting days, but it fails thereafter, and the failure worsens as we increase the horizon. Initially, the term structure of yield responses to the short rate shock is steep and downward sloping when plotted against

[1] If news about future fundamentals is released on announcement, bond risk premia will only change if the conditional covariance between returns and the SDF is affected. Even if the stand-in investor has Epstein-Zin preferences, news about long-run consumption growth will not have this effect.

Figure 1: Impulse Response of U.S. Treasuries: All Regularly Scheduled FOMC Meetings



Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. Sample consists of all 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. We plot 2-standard-error bands around the IR. HAC standard errors computed with bandwidth 2 for$k \leq 50$.

maturity, consistent with the mean reversion that is observed in short rates. As time progresses, the entire impulse response curve shifts up and flattens, counterfactually suggesting that shocks to short rates are perceived to be quasi-permanent. Hence, the yield curve flattens on the announcement but gradually steepens thereafter. Eventually, Treasury prices revert back partially. This phenomenon is similar to the drift that has been documented for stock prices after earnings announcements (Bernard and Thomas, 1989; Chan, Jegadeesh, and Lakonishok, 1996), except that there is no evidence of initial under-reaction in Treasury markets.

We find direct evidence that these deviations from the expectations hypothesis are due to price pressure. After Fed Funds target rate increases, bond mutual funds experience strong outflows. Mutual fund investors directly contribute to the sluggish adjustment by withdrawing investments from short and intermediate bond mutual funds, but only after the FOMC actually raises the Fed Fund target rate. Target rate changes are more salient to mutual fund investors.

Larger rate increases lead to larger bond mutual fund outflows, increasing the supply of bonds to be absorbed by the marginal investor. In doing so, mutual fund investors help the Fed increase long-term rates. Consistent with the flow-induced price pressure hypothesis (Coval and Stafford, 2007; Greenwood and Thesmar, 2011; Falato, Hortacsu, Li, and Shin, 2016), the response of government bond mutual fund returns to the Fed Funds surprises is even stronger and more persistent than the response predicted from on-the-run Treasury yields. The average fund has a duration of 5 years. After 50 days, the impact on returns is 12.86 bps per bps surprise, far greater than the 7.05 bps (5 times 1.41) implied by the yield estimates; Treasurys that are held predominantly by mutual funds decline more in value than others, and the effect is more persistent. Mutual fund investors distort long rates away from the response implied by the benchmark expectations hypothesis after changes in the Fed Funds target rate. Mutual fund investors thus help the Fed control long rates. We also show that monetary surprises predict subsequent fixed income mutual fund returns up to 50 days after the FOMC meeting.

The post-FOMC announcement drift is pervasive in U.S. bond markets. We find even stronger inertia in the responses of long yields in U.S. corporate bond markets and TIPS markets, as well as swap rates. These effects are robust to controlling for news about the path of future short rates and changes in growth and inflation expectations (Nakamura and Steinsson, 2013). We also examined the foreign bond markets of countries which feature an equivalent futures contract traded on the reference interest rate. There is a quantitatively similar overreaction pattern in the response of long rates in Australia, the U.K., Germany, and Switzerland to news about the short rates. Only Canada and New Zealand's long rates do not respond in the same way to news about short rates.

Mutual fund flows respond to an individual fund's past returns (Chevalier and Ellison, 1997; Sirri and Tufano, 1998). In general, past fund returns can be interpreted as a signal of manager skill (Berk and Green, 2004), but not in this case. After a surprise rate increase, a typical bond fund experiences negative fund returns on the FOMC announcement day. In response to these completely exogenous negative returns, mutual fund investors pull money out of government bond and other fixed income funds, even though these returns are not informative about skill. These fund outflows are triggered only when the Fed actually changes the target rate. On these days, the surprises are not only larger but also more salient to mutual fund investors. This suggests that more attention on the part of less sophisticated investors can contribute to larger drift in prices after a shock.[2] While it may be rational for

[2] In contrast, there is a large literature documenting slow incorporation of new information into prices when investors pay less attention. Dellavigna and Pollet (2009) documents larger earnings announcement drift on Fridays, when investors are less likely to pay attention (see Hirshleifer, Lim, and Teoh, 2018; Fedyk,

mutual fund investors to pay more attention to monetary surprises when the FOMC meets, simply because more payoff-relevant information is released on these days, it is harder to rationalize why they only seem attentive to target rate changes.

Even in deep markets, demand curves slope down (see Shleifer, 1986; Mitchell, Pulvino, and Stafford, 2004; Coval and Stafford, 2007; Lou, Yan, and Zhang, 2013). A large literature investigates the effect of supply shocks in Treasury markets (Krishnamurthy, 2002; Han, Longstaff, and Merrill, 2007; Krishnamurthy and Vissing-Jorgensen, 2011, 2012; Swanson, 2011; Greenwood and Vayanos, 2014). Our paper contributes to this literature by estimating the elasticity of the demand for Treasurys using FOMC-induced exogenous variation in fund flows. We use these exogenously induced flows to estimate the elasticity of the demand curve. The implied elasticity of Treasury prices with respect to the quantity of Treasurys is roughly 0.44: the price of outstanding Treasurys declines by 0.44% when the supply increases by 1%. The implied semi-elasticity of yields is around 0.089: yields increase by 8.9 bps for every 1% increase in the supply. This effect is not uniform across the maturity spectrum, but it is more pronounced for longer maturity Treasurys: Funds which hold longer maturity Treasurys experience larger negative returns.

Our findings suggest a novel monetary transmission mechanism that operates through delegated asset management, combined with downward sloping demand curves. We estimate the short-run demand for Treasurys to be inelastic. We refer to this as the mutual fund channel of monetary policy.

This outward shift in the supply of longer maturity Treasurys driven by backward looking bond mutual fund investors generates time-series momentum in Treasurys and other fixed income asset classes that covaries across asset classes, as documented by Moskowitz, Ooi, and Pedersen (2012). Time-series momentum –a security's own past returns predicts its future returns in various asset classes –is pervasive across asset classes including Treasurys (see Moskowitz, Ooi, and Pedersen, 2012). Asset classes that have performed well in the past months or year continue to outperform. Time-series momentum returns are correlated across asset classes, but the source of correlation is unclear. Our work identifies macro announcements as a potential source of correlation across asset classes. We find that macro announcements induce time-series momentum in long-term Treasurys. We refer to this as macro momentum.

There is a growing body of evidence that arbitrage capital moves slowly, even in response to anticipated events, even in developed, liquid asset markets: index reconstitutions in the

2017, for more recent work).

stock market (Shleifer, 1986; Greenwood, 2008) and Treasury auctions (Lou, Yan, and Zhang, 2013) are two prominent examples of repeated, anticipated supply shocks that have large price effects (see Duffie, 2010, for an overview of the emerging literature on slow-moving capital in asset pricing). We argue that FOMC announcements are a textbook example of shocks to the effective supply of Treasurys, because of the response of bond mutual fund investors, and the slow subsequent response of arbitrage capital. As a result of the slow response, the short-run demand for Treasurys is not perfectly elastic. In fact, rather than lean against the wind by providing liquidity to Treasury markets, speculative investors choose to exploit time-series momentum by taking short (long) Treasury futures positions in the days and weeks following surprise interest rate increases (decreases). These positions are proportional to the size of the shock. Net short positions in 10-year Treasury Note futures increase by 30% as a proportion of open interest after a surprise 100 bps increase.

The rest of the paper is organized as follows. Section 2 describes explains how we use monetary surprises in the data. Section 3 estimates the dynamic impulse response of Treasury yields to surprises in the Fed Funds rate. Section 4 describes the response of bond mutual fund returns and mutual fund flows to Fed Funds rate surprises, and we estimate the elasticity of the demand for Treasurys. Section 5 discusses the robustness of our findings: we control for news about the future path of interest rates, we control for changes in expectations around FOMC meetings, and we control for past Fed Funds surprises and the release of the Fed's minutes. Our main findings do not change.

2 Measuring News about the Short Rate

High-frequency identification of the effects of monetary policy has become standard in modern macroeconomics and asset pricing (see, e.g. Krishnamurthy and Vissing-Jorgensen, 2011; Nakamura and Steinsson, 2013; Hanson and Stein, 2015; Gertler and Karadi, 2015, for recent examples). To measure the actual shock to interest rates, econometricians use the innovation in the Fed Funds futures prices in a short window. Typically, researchers have used the nearest Fed Funds futures contract to extract the surprise shock to the Fed Funds target on FOMC announcement days (Rudebusch, 1998; Kuttner, 2001; Gürkaynak, Sack, and Swanson, 2005b; Cochrane and Piazzesi, 2002; Bernanke and Kuttner, 2005). News about future Fed Funds target rates can be extracted from Eurodollar deposit contracts with longer tenors (Gürkaynak, Sack, and Swanson, 2005b, 2007; Nakamura and Steinsson, 2018).

We use Fed Funds Futures changes to measure news about the level of the short rate.

We use Kuttner (2001)'s measure for the 1-day surprise on day t:

$$\Delta r_t^u = \left(f_t^0 - f_{t-1}^0\right) \frac{m}{m-t}. \tag{1}$$

where m is number of days in month and f_t^0 is the Fed Fund futures price for contract that expires at end of this month. On the last 3 days of month, we use $\left(f_t^1 - f_{t-1}^1\right)$ instead, where f_t^1 is the Fed Fund futures price for contract that expires at end of next month. After 1994, t is the date at which the target change is announced, typically the second day of the FOMC meeting. Before 1994, t is the next trading day after the last day of the FOMC meeting. Piazzesi and Swanson (2008) show that Kuttner (2001)'s and Bernanke and Kuttner (2005)'s surprise measure is robust to risk premium contamination. Our identifying assumption is that the risk premium component does not change between t and $t-1$. Under those conditions, this surprise measures the innovation in the expected Fed Funds rate.[3]

Panel A of Table 1 reports summary statistics for the surprise measure around regularly scheduled FOMC meetings. The first column reports statistics for all trading days covered by the sample. The second column considers all 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. After October 2008, there are no changes to the target until December 2015. We chose to end our baseline sample in October 2008, because the FOMC changed its operating procedure when it increased the Fed Funds rate in December 2015. We will check that our results are robust to extending the sample. To do so, we compute Kuttner's surprise measure on the official dates of the regularly scheduled FOMC meetings.

The volatility is more than three times higher on FOMC meeting days than on other days. On FOMC meeting days, the mean surprise is -0.99 basis points with a volatility of 6.78 basis points, compared to 1.84 basis points in the overall sample. The mean of the absolute value of the surprises is 3.90 basis points. Surprisingly, there is substantial negative autocorrelation in the 'surprise' measure; the first-order daily autocorrelation is -0.211. The Federal Reserve FOMC changed its operating procedure in 1994, when it explicitly announced the Fed Funds target. After this, the date of the change is the actual last day of the FOMC meeting. The moments of surprises do not differ much across these subsamples.

Panel B (C) of Table 1 reports the results same summary statistics for Kuttner (2001)

[3] We downloaded Kuttner's monetary surprise measure from his web site at https://econ.williams.edu/faculty-pages/research/. There are several instances in which Kuttner's timing deviates from the official FOMC timing. The Kuttner series ends in 2008. We obtain the dates of the remaining FOMC meetings from the Federal Reserve Board website at http://www.federalreserve.gov.stanford.idm.oclc.org/monetarypolicy/fomccalendars.htm.

surprises around (non-)target change FOMC meetings. There are 59 recorded changes in the Fed Funds target on regularly scheduled FOMC meeting days. The standard deviation on target change days increases to 9.58 basis points, compared to 4.302 basis points on non-change FOMC meeting days. Remarkably, the negative autocorrelation is not present when we only consider target changes. Finally, Panel C of Table 1 reports the results same summary statistics for Kuttner (2001) surprises around non-target changes. The standard deviation on non-target-change days is only 4.30 basis points, but the surprises are more leptokurtic. We detect strong positive autocorrelation of 0.15 in surprises on non-target-change days. Clearly, the Kuttner surprises are not quite i.i.d over time. There is surprising evidence of serial correlation that varies depending on whether the Fed announces a target change, consistent with Cieslak (2018)'s findings of persistent short rate forecast errors. We will devise econometric methods that are robust with respect to the serial correlation in surprises.

Table 1: Surprises on Scheduled FOMC Meeting Days

	All	**Full**	**Post-1994**	**Pre-crisis**
Panel A: All Scheduled				
Obs	6760	157	120	144
Mean	-0.093	-0.992	-0.748	-0.778
Mean(abs)	0.164	3.906	3.794	3.583
Std	1.849	6.786	6.280	6.416
Skewness	-18.249	-1.334	-0.487	-1.578
Kurtosis	534.328	8.538	5.645	10.211
AC(1)	-0.003	-0.211	-0.248	-0.227
Panel B: Target Changes				
Obs	6760	59	53	51
Mean	-0.093	-1.778	-0.375	-1.098
Mean(abs)	0.164	6.456	5.432	5.804
Std	1.849	9.587	7.984	9.102
Skewness	-18.249	-0.854	-0.220	-1.204
Kurtosis	534.328	4.901	3.760	6.243
AC(1)	-0.003	0.047	0.077	0.042
Panel C: No Target Changes				
Obs	6760	98	67	93
Mean	-0.093	-0.519	-1.043	-0.602
Mean(abs)	0.164	2.371	2.498	2.366
Std	1.849	4.302	4.549	4.344
Skewness	-18.249	-1.502	-1.791	-1.517
Kurtosis	534.328	9.424	8.938	9.386
AC(1)	-0.003	0.157	0.246	0.166

Summary statistics for Kuttner (2001) surprise in Federal Funds Rate. Sample: 10/1/1982-10/29/2008. Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The post-1994 sample contains 120 FOMC meetings after 22-Dec-1993.The pre-crisis sample contains 144 regularly scheduled FOMC meetings between 5-June-1989 and 09-May-2007. Full sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The pre-crisis sample contains 51 Fed Funds target changes between 5-June-1989 and 09-May-2007. The post-1994 sample contains 53 FOMC meetings after 22-Dec-1993.

3 Dynamic Response of Yields to News about Short Rate

High-frequency identification implicitly relies on the assumption of frictionless asset markets. In frictionless markets, bond prices will adjust instantaneously to the release of new information about the Fed Funds target within the event window: A deep pool of arbitrageurs with access to large amounts of arbitrage capital is always available to eliminate price discrepancies along the yield curve. The entire effect of the target surprise on bond yields can be captured even in a short event window. Researchers use OLS methods in the event window to gauge the effects of monetary surprises on asset prices (see Kuttner, 2001; Cochrane and Piazzesi, 2002; Nakamura and Steinsson, 2018).[4] Instead, we will use a longer event window to study the response of yields.

3.1 Data

The U.S. Treasury yields are from the U.S. Treasury Constant Maturity Series (downloaded from Datastream). These are par yields interpolated by the Treasury from the daily yield curve using a cubic spline model on bid-side yields for on-the-run Treasury securities. The Treasury uses other yields if no on-the-run yields are available for a given security. We use Moody's Seasoned AAA and BAA Corporate Bond Yield. These instruments are based on bonds with maturities 20 years and above. Moody's tries to include bonds with remaining maturities as close as possible to 30 years. Moody's drops bonds if the remaining life falls below 20 years, if the bond is susceptible to redemption, or if the rating changes. We also use the CMT TIPS series constructed by the Treasury (downloaded from Datastream). Finally, we use the ICAP U.S. Swap rate series provided by Datastream available at daily frequencies as a source of swap rates. We use Kuttner's monetary surprise series, available from his web site. We use the Bloomberg daily yield series for Australia, Canada, the U.K., Germany, Switzerland, and New Zealand.

3.2 Estimation

We use y_t^k to denote the par bond yield on a Treasury bond with maturity k. To compute the impulse responses, we run regressions of cumulative yield changes between $t-1$ and $t+j-1$ on the monetary policy surprise at t:

$$y^k_{\tau_i+j-1} - y_{\tau_i-1} = a_{k,j} + b_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots. \tag{2}$$

[4] See Cook and Hahn (1989) for an early use of the event window approach.

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings. Typically, it is assumed that the policy surprise is orthogonal to that day's current bond yield innovations. Under the null of efficient markets and rational expectations, these Δr_t^u are i.i.d. over time and uncorrelated with the residuals $\varepsilon_{t+j}^{k,j}$.[5] Under these conditions, the OLS estimator is unbiased and consistent. The slope coefficients $b_{k,j}, j = 1, 2, , \ldots$ trace out the impulse response of the Treasury yields to a monetary policy surprise. Focussing on FOMC meeting days is a sensible econometric strategy because most of the variation in yields on those days is due to the Fed Funds surprises (Rigobon and Sack, 2004).

These surprises are not truly exogenous, but these are controlled by the FOMC, who in turn respond to information revealed on that day. As a result, the right hand side variables potentially co-vary with the innovations $\varepsilon_{t+j}^{k,j}$. That would render the slope coefficients biased. In particular, we worry that the release of negative macro news at t would jointly lead to negative surprises and increases in Treasury prices (and decreases in the yields). If anything, this would bias the impact slope coefficients at $j = 1$ upwards. As a result, these slope coefficients may not be reliable estimates of the effect of a monetary policy surprise on bond yields. In addition, the Fed may respond to information at t that is only subsequently revealed to the market. Finally, for short horizons of less than 20 trading days ($j \leq 20$), there is no time overlap between subsequent regularly scheduled FOMC meetings. However, at longer horizons, the change in yields may comprise the subsequent FOMC meeting. We will deal with each these of econometric challenges in section 5.

3.3 Treasurys

We start in Treasury markets. The estimated slope coefficients are reported in Table 2, which reports the impact of Kuttner surprises on all regularly scheduled FOMC meeting days. For the 3-month bond, the same-day response of yields is 54 basis points. At the one-year maturity, the initial impact is 54 basis points. However, the impact gradually increases to 141 basis points at the 50-day horizon. The response of longer maturity bonds is more puzzling. We observe similar patterns for bonds with maturities in excess of one year. For the 10-year bond, the impact is only 17 bps at impact, but the cumulative effect after 50 days is 141 basis points. The cumulative impact on yields after 50 days is more than 100 basis points larger than the initial impact.

We plot the dynamic impulse-responses of Treasury yields to monetary policy surprises

[5]Strictly speaking, these surprises are only conditionally mean zero and uncorrelated over time under the risk-neutral measure.

in Figure 1 for the 3-month, 1-year, 3-year and 10-year zero coupons with 2 standard-error bands on each side. Consistent with the literature, we find that the initial pass-through of monetary policy surprises to short-term bond yields (e.g., the one-year bond) is around 60%, but the impact is only only 20% for bonds with maturities in excess of 10 years. However, the long-run impact of the policy surprise at 50 days increases with the maturity from 1 years to 5 years, and only gradually declines after that. Treasury yields on longer maturity bonds initially underreact and subsequently overreact to the short rate surprises.

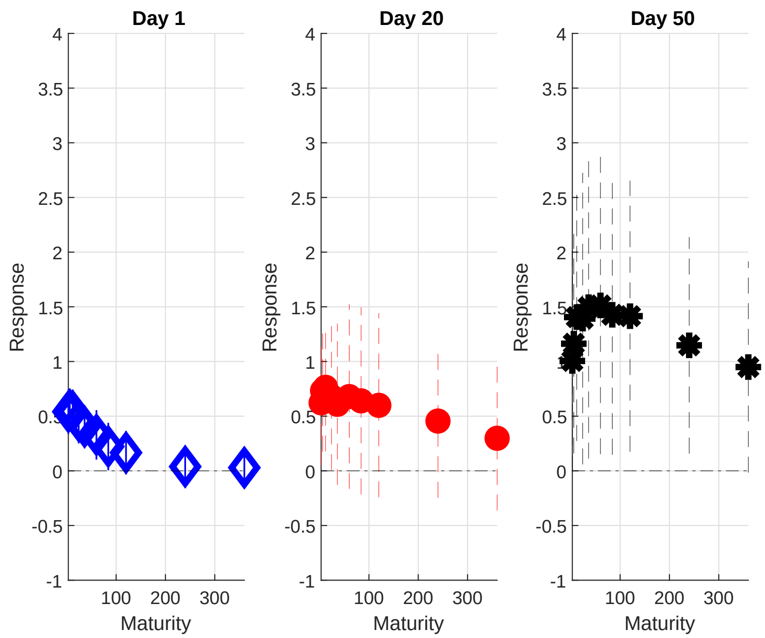
Table 2: Impulse Response of U.S. Treasury Yields

	1	**5**	**10**	**20**	**50**	**100**
3 MTH	0.54	0.60	0.60	0.62	1.00	0.92
	[0.06]	[0.14]	[0.24]	[0.27]	[0.49]	[0.88]
	(0.10)	(0.17)	(0.21)	(0.29)	(0.50)	(0.70)
	0.37	0.11	0.04	0.03	0.03	0.01
6 MTH	0.56	0.57	0.64	0.73	1.16	1.07
	[0.05]	[0.13]	[0.18]	[0.26]	[0.51]	[0.90]
	(0.08)	(0.18)	(0.19)	(0.28)	(0.50)	(0.73)
	0.42	0.11	0.08	0.05	0.03	0.01
1 YR	0.54	0.62	0.66	0.76	1.41	1.15
	[0.06]	[0.14]	[0.20]	[0.28]	[0.54]	[0.93]
	(0.10)	(0.20)	(0.24)	(0.29)	(0.57)	(0.79)
	0.36	0.12	0.07	0.05	0.04	0.01
2 YR	0.46	0.54	0.58	0.68	1.39	0.93
	[0.08]	[0.17]	[0.23]	[0.32]	[0.59]	[0.96]
	(0.10)	(0.23)	(0.27)	(0.34)	(0.67)	(0.89)
	0.18	0.06	0.04	0.03	0.03	0.01
3 YR	0.40	0.51	0.48	0.61	1.50	0.84
	[0.08]	[0.17]	[0.23]	[0.33]	[0.60]	[0.96]
	(0.10)	(0.23)	(0.27)	(0.37)	(0.69)	(0.91)
	0.14	0.06	0.03	0.02	0.04	0.00
5 YR	0.33	0.46	0.49	0.68	1.51	0.80
	[0.08]	[0.17]	[0.23]	[0.34]	[0.57]	[0.88]
	(0.11)	(0.21)	(0.24)	(0.42)	(0.68)	(0.83)
	0.09	0.05	0.03	0.03	0.04	0.01
7 YR	0.22	0.42	0.39	0.64	1.43	0.66
	[0.07]	[0.16]	[0.22]	[0.32]	[0.52]	[0.80]
	(0.11)	(0.19)	(0.22)	(0.43)	(0.64)	(0.77)
	0.06	0.04	0.02	0.03	0.05	0.00
10 YR	0.17	0.30	0.28	0.60	1.41	0.66
	[0.07]	[0.15]	[0.21]	[0.31]	[0.48]	[0.73]
	(0.10)	(0.17)	(0.20)	(0.42)	(0.62)	(0.72)
	0.04	0.02	0.01	0.02	0.05	0.01
20 YR	0.04	0.27	0.27	0.46	1.15	0.64
	[0.06]	[0.14]	[0.18]	[0.27]	[0.42]	[0.61]
	(0.10)	(0.14)	(0.17)	(0.35)	(0.50)	(0.59)
	0.00	0.02	0.01	0.02	0.05	0.01
30 YR	0.03	0.23	0.18	0.30	0.95	0.20
	[0.06]	[0.14]	[0.18]	[0.26]	[0.40]	[0.60]
	(0.09)	(0.15)	(0.17)	(0.33)	(0.48)	(0.59)
	0.00	0.02	0.01	0.01	0.03	0.00

Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. OLS (HAC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

Figure 2 plots the term structure of these responses at impact (left panel), after 20 days (middle panel) and after 50 days (panel on the right). The initial impact varies from 60 basis points at the short end to zero at the long end. The term structure of responses is quite steep, as dictated by the expectations hypothesis. After 20 days, the impact varies from 75

Figure 2: Term Structure of U.S. Treasury Responses: All FOMC Meetings



Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. Sample consists of all 157 regularly scheduled FOMC meetings between 5-June-1989 and 03/15/2015. HAC standard errors computed with one lag for $k \leq 50$.

basis points at the short end to 20 basis points at the long end. The term structure has flattened. At 50 days, the entire curve has shifted up, and the curve is hump-shaped. The impact varies from 100 basis at the short end to 150 basis points for intermediate bonds, back down to 100 basis points for long bonds.

In the simplest term structure model, the short rate follows an AR(1) process:

$$y_{t+1}^1 - \delta = \rho(y_t^1 - \delta) + \varepsilon_{t+1}.$$

The expectations hypothesis implies that the long yield is driven only by the short rates:

$$y_t^N - \delta = \frac{1}{N}\frac{1-\rho^{N+1}}{1-\rho}(y_t^1 - \delta). \tag{3}$$

The loading of the long rate on the short rate is determined by the persistence of the short rate process. It is natural to assume that the expectations hypothesis holds for monetary surprises. If we compare the initial impact across maturities, then the response of the one-year bond (54 bps) is consistent with a monthly (annual) persistence in the short rate of 0.875 (0.20). The response of the 10-year bond (0.17) bps is consistent with a persistence closer to 0.95 (0.54). The response of the 10-year bond seems too large relative to the response of the 1-year bond. If we back out persistence from the ratio of the 10-year to the 1-year response, we get even higher monthly (annual) persistence of 0.975 (0.69). The initial impact of monetary surprises on yields seems broadly consistent with the expectations hypothesis provided that the short rates are not too persistent.

The expectations hypothesis seems to hold on FOMC meeting days, consistent with the findings of Savor and Wilson (2014), but not thereafter. After 20 days, the term structure is still downward sloping, but we need an even higher monthly (annual) persistence of 0.995 (0.94) to match the 10-year yield's response to the 1-year response. Finally, after 50 days, the response of the 1-year bond is 141 bps., while the response of the 10-year is also 141 bps. These estimates are impossible to reconcile with the expectations hypothesis, unless the short rate shocks are perceived to be permanent by investors. These findings are fairly robust. They survive even when end the sample before the crisis (May 2007) (see Table A1 in the Appendix). However, there are sizeable differences between the response to surprises on FOMC meeting days when the target rate was (not) changed.

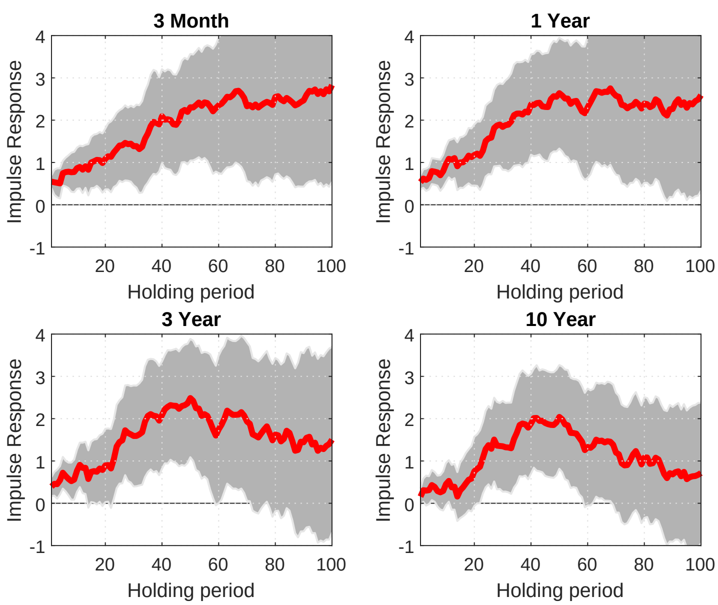
This evidence is puzzling, mainly for three reasons. First, it is hard to see why the impact on the 1-year exceeds the size of the Fed Funds rate surprise itself. This could be due to news about imminent interest rate changes in the next few months. In this case, we are overestimating the effect of the Fed Funds rate surprise. We will control for news about future interest rates in the robustness section. Second, after 50 days, investors implicitly seem to assume that shocks to the short rate are quasi-permanent; we need a unit root in the short rate process to rationalize the impact on the 1-year and the 10-year. Clearly, the expectations hypothesis seems to fail after impact. Third, the perceived persistence of the short rate seems to increase over time, according to these estimates. This evidence is consistent with the time-series momentum documented by Moskowitz, Ooi, and Pedersen (2012). In government bond markets, they find that a look-back window of 1 to 2 months is optimal, roughly in line with the reversal we see after 50 trading days.

3.4 Changes in the Fed Funds Target Rate

These effects are entirely driven by changes in the Fed Funds target rate. Surprises on these days are about twice as large, and the surprises are obviously more salient to mutual fund investors. Next, we estimate separate impulse responses for FOMC meeting days on which the target rate was changed. Figure 3 plots the impulse-response of yields to the monetary surprises on target-change days. We plot 2-standard-error bands around the impulse responses. On target-change days, the response of yields to the surprise builds up gradually over time. The response is statistically significantly different from zero, even at longer horizons. After 50 days, there is evidence of mean reversion in the long rates.

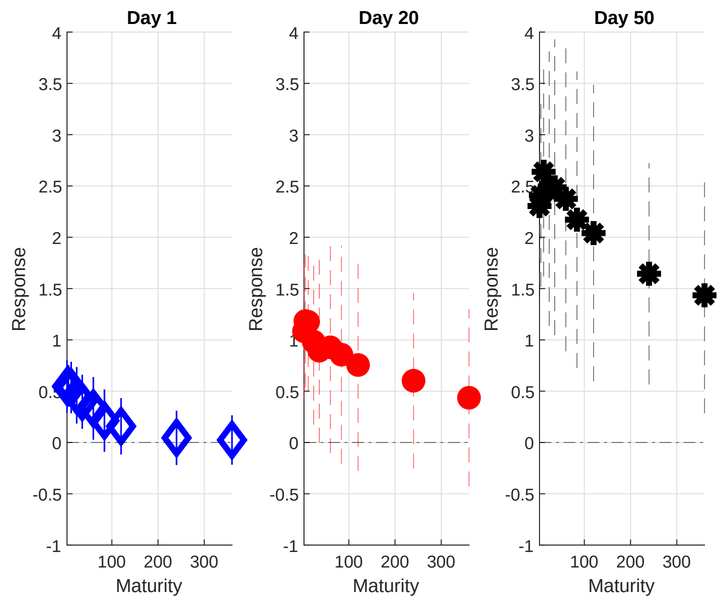
Figure 4 plots the term structure of responses on impact, after 20 days and after 50 days. As we go out further in time, the deviations from the expectations hypothesis benchmark become more pronounced. After 50 days, the entire term structure of responses exceeds 150% of the initial shock. The details are in Table 3. Panel A of Table 3 reports results for the same regressions using only non-target change surprises; Panel B uses only target-change surprises. The surprises on these non-target-change days have much lower explanatory power for subsequent changes in bond yields, especially for longer maturity bonds. Most of the explanatory power derives from surprises on target change days. As an example, take the 1-year Treasury. The R^2 upon impact is 0.26 on non-target-change days, compared to 0.41 on target change days. More surprising is that the R^2 stays high long after impact, but only after target changes. Fifty days after a target change, the R^2 is 0.22 for the one-year yield; only 0.04 after non-target-change days. In fact, for longer maturity bonds, the R^2 actually increases from impact to day 50.

Figure 3: Impulse Response of U.S. Treasuries: Target Changes



Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. Full sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC standard errors computed with one lag for $k \leq 50$.

Figure 4: Impulse Response of U.S. Treasuries: Target Changes



Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. Full sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC standard errors computed with one lag for $k \leq 50$.

Table 3: Impulse Response of U.S. Treasuries on FOMC Meeting Days

Panel A: No Target Changes

	1	5	10	20	50	100
3 MTH	0.46	0.08	-0.22	-0.75	-2.75	-4.18
	[0.10]	[0.29]	[0.52]	[0.46]	[0.79]	[1.47]
	(0.15)	(0.41)	(0.51)	(0.53)	(0.99)	(1.16)
	0.19	0.00	0.00	0.03	0.11	0.08
6 MTH	0.51	0.10	-0.07	-0.60	-2.36	-3.24
	[0.08]	[0.26]	[0.35]	[0.46]	[0.85]	[1.57]
	(0.13)	(0.40)	(0.38)	(0.54)	(1.04)	(1.27)
	0.29	0.00	0.00	0.02	0.07	0.04
1 YR	0.52	0.11	-0.18	-0.41	-1.97	-2.29
	[0.09]	[0.28]	[0.40]	[0.50]	[0.97]	[1.70]
	(0.14)	(0.41)	(0.41)	(0.53)	(1.13)	(1.33)
	0.26	0.00	0.00	0.01	0.04	0.02
2 YR	0.43	-0.05	-0.27	-0.14	-1.39	-0.79
	[0.13]	[0.32]	[0.46]	[0.58]	[1.11]	[1.84]
	(0.14)	(0.40)	(0.41)	(0.49)	(1.17)	(1.34)
	0.10	0.00	0.00	0.00	0.02	0.00
3 YR	0.40	-0.06	-0.25	-0.14	-0.97	-0.09
	[0.14]	[0.33]	[0.47]	[0.62]	[1.15]	[1.86]
	(0.15)	(0.39)	(0.41)	(0.52)	(1.11)	(1.34)
	0.08	0.00	0.00	0.00	0.01	0.00
5 YR	0.28	-0.03	-0.19	0.01	-0.61	0.75
	[0.14]	[0.34]	[0.46]	[0.63]	[1.08]	[1.73]
	(0.16)	(0.36)	(0.40)	(0.52)	(1.01)	(1.21)
	0.04	0.00	0.00	0.00	0.00	0.00
7 YR	0.20	0.02	-0.13	0.07	-0.40	1.02
	[0.12]	[0.32]	[0.43]	[0.58]	[0.97]	[1.58]
	(0.13)	(0.32)	(0.37)	(0.50)	(0.91)	(1.11)
	0.03	0.00	0.00	0.00	0.00	0.00
10 YR	0.15	-0.06	-0.15	0.18	-0.14	1.20
	[0.11]	[0.31]	[0.41]	[0.58]	[0.89]	[1.44]
	(0.14)	(0.28)	(0.37)	(0.54)	(0.84)	(1.02)
	0.02	0.00	0.00	0.00	0.00	0.01
20 YR	-0.01	-0.04	-0.17	0.09	-0.08	1.59
	[0.09]	[0.27]	[0.35]	[0.49]	[0.76]	[1.15]
	(0.10)	(0.23)	(0.29)	(0.43)	(0.73)	(0.81)
	0.00	0.00	0.00	0.00	0.00	0.02
30 YR	-0.00	-0.08	-0.21	-0.06	-0.27	1.34
	[0.09]	[0.25]	[0.33]	[0.48]	[0.75]	[1.17]
	(0.10)	(0.21)	(0.27)	(0.40)	(0.69)	(0.78)
	0.00	0.00	0.00	0.00	0.00	0.01

Panel B: Only Target Changes

	1	5	10	20	50	100
3 MTH	0.55	0.75	0.86	1.08	2.30	2.83
	[0.08]	[0.15]	[0.24]	[0.36]	[0.63]	[1.15]
	(0.13)	(0.14)	(0.19)	(0.33)	(0.44)	(0.69)
	0.48	0.31	0.18	0.14	0.19	0.10
6 MTH	0.55	0.72	0.88	1.18	2.41	2.74
	[0.08]	[0.14]	[0.21]	[0.35]	[0.66]	[1.16]
	(0.10)	(0.17)	(0.19)	(0.32)	(0.45)	(0.79)
	0.48	0.31	0.23	0.17	0.19	0.09
1 YR	0.54	0.80	0.96	1.18	2.64	2.59
	[0.09]	[0.15]	[0.21]	[0.36]	[0.65]	[1.13]
	(0.13)	(0.19)	(0.25)	(0.34)	(0.51)	(0.86)
	0.41	0.32	0.27	0.16	0.22	0.08
2 YR	0.46	0.75	0.90	0.98	2.47	1.85
	[0.11]	[0.20]	[0.25]	[0.42]	[0.70]	[1.13]
	(0.14)	(0.25)	(0.29)	(0.40)	(0.67)	(0.98)
	0.22	0.20	0.19	0.09	0.18	0.05
3 YR	0.40	0.72	0.77	0.89	2.49	1.50
	[0.11]	[0.19]	[0.25]	[0.43]	[0.70]	[1.10]
	(0.13)	(0.25)	(0.32)	(0.45)	(0.72)	(0.99)
	0.18	0.21	0.14	0.07	0.18	0.03
5 YR	0.33	0.63	0.76	0.93	2.37	1.14
	[0.12]	[0.18]	[0.24]	[0.44]	[0.66]	[0.98]
	(0.15)	(0.24)	(0.28)	(0.52)	(0.74)	(0.99)
	0.12	0.17	0.14	0.07	0.18	0.02
7 YR	0.21	0.55	0.60	0.86	2.17	0.81
	[0.11]	[0.18]	[0.26]	[0.42]	[0.63]	[0.90]
	(0.15)	(0.23)	(0.28)	(0.53)	(0.72)	(0.93)
	0.06	0.15	0.09	0.07	0.17	0.01
10 YR	0.16	0.43	0.45	0.76	2.04	0.71
	[0.10]	[0.18]	[0.25]	[0.41]	[0.61]	[0.83]
	(0.14)	(0.21)	(0.24)	(0.52)	(0.72)	(0.93)
	0.04	0.09	0.06	0.06	0.16	0.01
20 YR	0.04	0.37	0.44	0.60	1.64	0.45
	[0.09]	[0.17]	[0.23]	[0.36]	[0.54]	[0.72]
	(0.13)	(0.19)	(0.22)	(0.43)	(0.54)	(0.75)
	0.00	0.08	0.06	0.05	0.14	0.01
30 YR	0.02	0.32	0.31	0.44	1.43	-0.02
	[0.08]	[0.18]	[0.23]	[0.35]	[0.51]	[0.70]
	(0.12)	(0.20)	(0.22)	(0.43)	(0.58)	(0.80)
	0.00	0.05	0.03	0.03	0.12	0.00

Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. OLS (HAC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 98 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008 without target changes. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

The sluggishness in the quantitative response to surprises is much more pronounced on days when the Fed funds target rate is changed than on other days. The initial impact is similar when we only consider target rate changes. For the 3-month bond, the same-day response of yields is 55 basis points. At the one-year maturity, the initial impact is 54 basis points. For all these bonds, we can reject the null that the initial impact equals 100 basis points. However, the subsequent response at longer horizons is quite different. Twenty days after a target change, the response of the 3-month (1-year) yield increases to a cumulative impact of 108 (118) bps. Fifty days after a target change, the cumulative response has increased to 230 (264) bps at the 3-month (1-year)-maturity.

For bonds with intermediate maturities, the initial impact is small but statistically significant. For example, consider the 5-year bond. The initial impact is 33 bps. However, after 50 days, the impact has increased to 237 bps per annum. This response is comparable to the response of the one-year.

Finally, we consider the impact on bonds with longer maturities. For the 20/30 year bonds, we cannot reject that the initial impact is zero. This is what the expectations hypothesis predicts, given the limited persistence of short term interest rates, like the Fed Funds rate. However, after 50 days, the cumulative response has increased to 164 bps (143) for the 20 (30)-year bonds. Given the limited persistence of the Fed Funds rate, it is puzzling that these long yields respond one-for-one to the Kuttner measure of monetary surprises. Furthermore, surprises explain about 14% of the 50-day variation in the 20-year yield, but none of the variation on the actual FOMC meeting day.

These results are robust across different samples. In the Appendix, Table A1 reports the result obtained on the pre-crisis sample that ends in May of 2007; Table A2 and Table A3 reports the results obtained on the longer sample that ends in May of 2018. This sample includes the zero-lower-bound episode from December of 2008 to 2015.

We also consider the results obtained when all rate changes, including the inter-meeting changes, are included in Table 4. This approach is more standard in the literature on this literature (see Bernanke and Kuttner, 2005; Gürkaynak, Sack, and Swanson, 2005b; Gertler and Karadi, 2015). Inter-meeting changes are different because these presumably occur directly in response to new information about fundamentals released on that day. In fact, before 1994, some of these meetings coincided exactly with the release of the Employment report. In these instances, the Fed Funds target rate change was triggered directly by the release. There are a total of 84 Fed Funds target rate changes in the sample. When we included the inter-meeting changes, the post-FOMC announcement drift is considerably weaker.

Table 4: Impulse Response of U.S. Treasuries including Inter-meeting Changes

Panel A: No Target Changes

	1	5	10	20	50	100
3 MTH	0.46	0.08	-0.22	-0.75	-2.75	-4.18
	[0.10]	[0.29]	[0.52]	[0.46]	[0.79]	[1.47]
	(0.15)	(0.41)	(0.52)	(0.56)	(1.02)	(1.23)
	0.19	0.00	0.00	0.03	0.11	0.08
6 MTH	0.51	0.10	-0.07	-0.60	-2.36	-3.24
	[0.08]	[0.26]	[0.35]	[0.46]	[0.85]	[1.57]
	(0.13)	(0.40)	(0.41)	(0.59)	(1.33)	(1.37)
	0.29	0.00	0.00	0.02	0.07	0.04
1 YR	0.52	0.11	-0.18	-0.41	-1.97	-2.29
	[0.09]	[0.28]	[0.40]	[0.50]	[0.97]	[1.70]
	(0.14)	(0.39)	(0.44)	(0.62)	(1.57)	(1.47)
	0.26	0.00	0.00	0.01	0.04	0.02
2 YR	0.43	-0.05	-0.27	-0.14	-1.39	-0.79
	[0.13]	[0.32]	[0.46]	[0.58]	[1.11]	[1.84]
	(0.13)	(0.37)	(0.45)	(0.59)	(1.61)	(1.51)
	0.10	0.00	0.00	0.00	0.02	0.00
3 YR	0.40	-0.06	-0.25	-0.14	-0.97	-0.09
	[0.14]	[0.33]	[0.47]	[0.62]	[1.15]	[1.86]
	(0.14)	(0.36)	(0.46)	(0.61)	(1.53)	(1.50)
	0.08	0.00	0.00	0.00	0.01	0.00
5 YR	0.28	-0.03	-0.19	0.01	-0.61	0.75
	[0.14]	[0.34]	[0.46]	[0.63]	[1.08]	[1.73]
	(0.15)	(0.35)	(0.44)	(0.60)	(1.34)	(1.33)
	0.04	0.00	0.00	0.00	0.00	0.00
7 YR	0.20	0.02	-0.13	0.07	-0.40	1.02
	[0.12]	[0.32]	[0.43]	[0.58]	[0.97]	[1.58]
	(0.13)	(0.31)	(0.41)	(0.55)	(1.18)	(1.20)
	0.03	0.00	0.00	0.00	0.00	0.00
10 YR	0.15	-0.06	-0.15	0.18	-0.14	1.20
	[0.11]	[0.31]	[0.41]	[0.58]	[0.89]	[1.44]
	(0.13)	(0.28)	(0.40)	(0.59)	(1.07)	(1.09)
	0.02	0.00	0.00	0.00	0.00	0.01
20 YR	-0.01	-0.04	-0.17	0.09	-0.08	1.59
	[0.09]	[0.27]	[0.35]	[0.49]	[0.76]	[1.15]
	(0.10)	(0.23)	(0.32)	(0.46)	(0.86)	(0.84)
	0.00	0.00	0.00	0.00	0.00	0.02
30 YR	-0.00	-0.08	-0.21	-0.06	-0.27	1.34
	[0.09]	[0.25]	[0.33]	[0.48]	[0.75]	[1.17]
	(0.09)	(0.21)	(0.30)	(0.43)	(0.84)	(0.82)
	0.00	0.00	0.00	0.00	0.00	0.01

Panel B: Only Target Changes

	1	5	10	20	50	100
3 MTH	0.53	0.80	0.76	1.04	1.94	2.38
	[0.05]	[0.09]	[0.14]	[0.21]	[0.35]	[0.61]
	(0.07)	(0.10)	(0.12)	(0.20)	(0.27)	(0.66)
	0.57	0.48	0.27	0.24	0.27	0.16
6 MTH	0.53	0.80	0.81	1.09	1.91	2.21
	[0.05]	[0.08]	[0.12]	[0.20]	[0.36]	[0.61]
	(0.06)	(0.08)	(0.10)	(0.18)	(0.27)	(0.65)
	0.57	0.53	0.34	0.26	0.25	0.14
1 YR	0.49	0.75	0.78	1.00	1.76	1.84
	[0.05]	[0.09]	[0.13]	[0.21]	[0.36]	[0.59]
	(0.07)	(0.10)	(0.11)	(0.18)	(0.28)	(0.62)
	0.50	0.48	0.32	0.22	0.22	0.10
2 YR	0.35	0.48	0.55	0.63	1.26	0.99
	[0.07]	[0.12]	[0.13]	[0.23]	[0.39]	[0.60]
	(0.08)	(0.13)	(0.13)	(0.19)	(0.34)	(0.63)
	0.23	0.17	0.17	0.08	0.11	0.03
3 YR	0.30	0.45	0.43	0.48	1.14	0.60
	[0.07]	[0.11]	[0.14]	[0.23]	[0.39]	[0.58]
	(0.08)	(0.13)	(0.14)	(0.21)	(0.36)	(0.60)
	0.18	0.16	0.11	0.05	0.09	0.01
5 YR	0.23	0.30	0.31	0.29	0.89	0.25
	[0.07]	[0.11]	[0.13]	[0.23]	[0.38]	[0.52]
	(0.09)	(0.12)	(0.14)	(0.23)	(0.37)	(0.50)
	0.11	0.08	0.06	0.02	0.06	0.00
7 YR	0.16	0.24	0.24	0.20	0.80	0.15
	[0.07]	[0.11]	[0.13]	[0.22]	[0.36]	[0.47]
	(0.09)	(0.11)	(0.14)	(0.23)	(0.35)	(0.45)
	0.06	0.06	0.04	0.01	0.06	0.00
10 YR	0.11	0.17	0.14	0.09	0.68	0.08
	[0.06]	[0.11]	[0.13]	[0.22]	[0.34]	[0.44]
	(0.08)	(0.10)	(0.13)	(0.23)	(0.34)	(0.43)
	0.04	0.03	0.01	0.00	0.05	0.00
20 YR	0.04	0.08	0.11	0.02	0.48	-0.04
	[0.05]	[0.10]	[0.12]	[0.19]	[0.30]	[0.36]
	(0.06)	(0.10)	(0.12)	(0.21)	(0.30)	(0.36)
	0.01	0.01	0.01	0.00	0.03	0.00
30 YR	0.02	0.04	0.01	-0.07	0.45	-0.17
	[0.05]	[0.10]	[0.12]	[0.18]	[0.28]	[0.36]
	(0.06)	(0.10)	(0.11)	(0.20)	(0.28)	(0.33)
	0.00	0.00	0.00	0.00	0.03	0.00

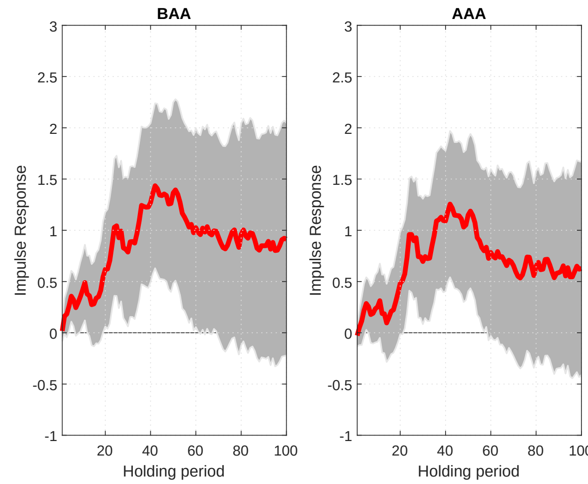
Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 98 regularly scheduled and unscheduled FOMC meetings between 5-June-1989 and 29-Oct-2008 without target changes. The sample contains 84 Fed Funds Target Changes on regularly scheduled and unscheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

3.5 Other Bond Markets

This evidence of sluggish adjustment is not limited to Treasuries. One potential concern may be that the Treasury CMT yields are obtained by fitting a curve. As an alternative to the Treasury Yields, we used ICAP Swap Rates. The results are reported in Table A4 in the Appendix.

Long-term corporate bond yields are directly relevant for cost of capital of U.S. corporations, which in turn determines the discount rate used when making investment decisions. There is stronger evidence in corporate bond yields of post-announcement drift in response to FOMC surprises. Figure 5 plots the impulse-responses for corporate bond yields. The panel on the left (right) plots the impulse response for BAA (AAA) bonds. In the case of

Figure 5: Impulse Response of U.S. Corporate Bond Yields



Impulse Response of U.S. Corporate Yields to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. Sample consists of all 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

corporate bonds, the deviation from the expectation hypothesis seems even stronger. The initial impact is close to zero for corporate bond yields. The muted response makes sense given that all of the bonds used to construct the index have maturities in excess of 20 years. However, after 50 days, the impact has increased to 137 (116) bps for BAA (AAA) bonds. These coefficient estimates are statistically significant as well. Table A5 in the separate Appendix reports the slope coefficient estimates. The slope coefficient estimates are significantly different from zero at 5 % significance.

Finally, we also confirmed that even larger effects are present in TIPS markets. The sample only starts in Table A6 in the separate Appendix reports results for real yields on 5-year TIPS. However, these effects are much smaller if we end the sample before the onset of the financial crisis, which suggests that this may reflect disruptions in TIPS markets in 2008 documented by Fleckenstein, Longstaff, and Lustig (2014).

Outside of the US, we constructed the monetary policy surprises for Australia, Canada, the Eurozone, New Zealand, Switzerland, UK, and the US. The surprises themselves are one-day rate changes of interest rate futures (3M Eurodollar and its international equivalents) around the announcement. The non-U.S. announcement dates and rates are pulled from Bloomberg and are checked against each bank's website. Our IRF methodology differs from Bernanke and Kuttner's (2005) use of Fed funds futures since Fed funds futures settle to an average fed funds rate over the month, while IRFs settle to the end of quarter intra-bank rate. The findings are broadly similar. In all of these countries, there is considerable post-FOMC drift of Treasury prices at the short end of the maturity spectrum. However, at the long end, there is no evidence of drift in Canadian and New Zealand bond markets. In all other markets, we find very similar results, including in the UK and German markets. Detailed results are reported in section C of the separate appendix.

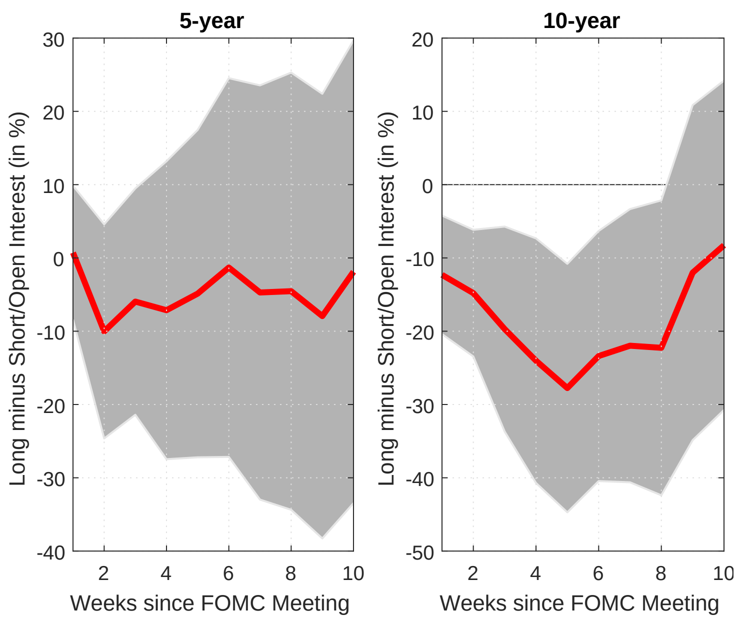
3.6 Speculative Investors: Leaning with the Wind

Rather than lean against the wind by providing liquidity to Treasury markets, speculative investors in bond markets choose to exploit time-series momentum by taking short (long) Treasury futures positions in the days and weeks following surprise interest rate increases (decreases). These positions are proportional to the size of the shock. Net short positions in 10-year Treasury Note futures increase by 30% as a proportion of open interest after a surprise 100 bps increase. We use the Open Interest data from the CFTC to measure speculative positions. Following the literature, the size of the speculative position is defined as

$$(\textit{NonCommercial Long minus NonCommercial Short})/\textit{NonCommercial Open Interest}$$

We focus on the 5-year and 10-year T-Note futures contracts. Speculative interest is 10 percentage points lower in the week after the FOMC announcement following a surprise rate increase. The decline peaks at 30 percentage points after 5 weeks, and then it gradually reverts. At least based on this evidence, sophisticated investors choose to trade with momentum. Greenwood and Thesmar (2011) found that mutual fund flows have larger effects on stock prices when arbitrageurs trade in the same direction. Arbitrageurs in Treasury markets do not lean against the wind. However, there is not enough arbitrage capital for prices to adjust quickly. In that sense, this evidence is consistent with the evidence from index reconstitutions in the stock market (Shleifer, 1986; Greenwood, 2008) and Treasury auctions (Lou, Yan, and Zhang, 2013).

Figure 6: Impulse Response of Speculative Interest



Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. Full sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008.

4 Mutual Fund Investors' Response to News about Short Rate

Delegated asset management plays a major role in bond markets. In 2017 Q2, The total supply of marketable Treasurys is $13.965 trillion. $5.585 trillion is held by foreigners, much of this is held by China and Japan at central banks and sovereign wealth funds. If we think of foreign demand as inelastic, the relevant total supply of Treasurys is only $8 trillion. U.S. mutual funds held $889.3 billion in Treasurys. Money market mutual funds hold another $624.3 bn in Treasurys.[6] U.S. mutual and money market funds hold about 11.6% of the total supply of Treasurys, compared to 1.7% for insurance companies, 3.2% for pension funds and 3.3% for banks. 30.7% of the federal government debt is held by foreigners, but foreign demand for Treasurys is rather in-elastic (Krishnamurthy and Vissing-Jorgensen, 2007). Delegated asset managed is quantitatively important in U.S. fixed income markets.

4.1 Bond Mutual Fund Data

We use the Lipper classification codes to identify government bond funds in the CRSP mutual fund data. We define government bond funds as (IUT) Treasury Inflation Protected Securities, Short U.S. Government Funds (SUS), Short U.S. Treasury Funds (SUT), Intermediate U.S. Government Funds (IUG), Short-Intermediate U.S. Government Funds (SIU), General U.S. Government Fds (GUS) , and, finally, General U.S. Treasury Funds (GUT). We define corporate bond funds as Quality Corporate Debt Funds A Rated (A) and Corporate Debt Funds BBB-Rated (BBB) . Finally, we define Money Market Funds to include Instl Money Market Funds (IMM), Instl Tax-Exempt Money Market Funds (ITE), Instl U.S. Treasury Money Market Funds (ITM), Instl U.S. Government Money Market Funds (IUS), Money Market Fund (MMF) Tax-free Money Market (TFM) Taxable Money Market (TMM), Money Market Funds (MM), Tax-Exempt Money Market Funds (TEM) U.S. Government Money Market Funds (USS), U.S. Treasury Money Market Funds (UST). Hence, we exclude the Muni market.

[6]Mutual funds hold another $ 652 bn. in agency and GSE-backed securities, $667.6 bn. in municipal securities and $1,995 bn. in corporate bonds and foreign bonds. Money market mutual funds hold another $642.9 bn in agency and GSE-backed securities. Another $109 bn is held in ETFs. (source: U.S. Federal Flow of Funds).

4.2 Mutual Fund Return Dynamics

The Treasury constructs the yield curve that we used from on-the-run Treasurys. We start by looking at the impact of Fed Funds rate surprises on mutual fund returns, because this provides a sharper picture of the actual impact on the valuation of a portfolio that includes all Treasurys, using actual transaction prices. We use CRSP Mutual Fund data to gauge the effect of monetary surprises on mutual fund returns and flows. The flow data is collected monthly. We have end-of-month data on Total Net Assets and Flows for all bond mutual funds in the U.S. We have daily return data starting in 1998. We report equal-weighted mutual fund returns, because we do not have daily TNA data. However, we checked that value-weighted monthly results are essentially identical to the equal-weighted results. We run the following regression of cumulative log returns on the surprise:

$$r^k_{\tau_i \to \tau_i + j - 1} = a_{k,j} + b_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i + j - 1}, j = 1, 2, \ldots. \tag{4}$$

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings.

Table 5: Impulse Response of U.S. Government Bond Mutual Fund Returns

Panel A: All Scheduled FOMC Meetings

1	5	10	20	50	100
-1.48	-5.09	-5.22	-7.10	-12.86	-10.90
[0.68]	[1.52]	[2.00]	[2.92]	[3.96]	[5.37]
(0.71)	(1.71)	(2.56)	(3.24)	(4.68)	(4.71)
0.06	0.12	0.08	0.07	0.12	0.05

Panel B: Target Changes

1	5	10	20	50	100
-1.38	-4.91	-5.82	-7.10	-14.45	-11.55
[0.73]	[1.66]	[2.03]	[3.09]	[4.30]	[5.28]
(0.76)	(1.98)	(2.41)	(3.45)	(5.05)	(4.76)
0.08	0.18	0.17	0.11	0.22	0.10

Panel C: No Target Changes

1	5	10	20	50	100
-0.80	-6.12	-2.10	-5.32	4.87	-13.69
[2.32]	[5.32]	[7.44]	[10.57]	[13.64]	[20.55]
(2.74)	(6.00)	(9.92)	(10.16)	(10.89)	(19.73)
0.00	0.03	0.00	0.01	0.00	0.01

Impulse Response of U.S. government bond mutual fund cumulative log returns in percentage points to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days: $r^k_{\tau_i \to \tau_i + j - 1} = a_{k,j} + b_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i + j - 1}, j = 1, 2, \ldots$. OLS (HAC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

Table 5 tabulates the response of returns on all government bond funds to a 100 basis point surprise. Panel A considers all FOMC meeting days. On the first day, a typical investor in a US government bond mutual fund loses 1.48 bps per 1 bps short rate surprise. In the first 5 days, that number rises to 5.09 bps. And finally, the impact after 50 days is 12.86 basis points. After a target change, these numbers change to 1.38 bps, 4.91 bps and, finally, 14.45 bps per 1 bps surprise.

Upon impact, the typical U.S. government bond mutual fund seems to have a duration of roughly 5 years: 148 bps. divided by 5 is roughly 30 basis points, the response of the 6-year yield reported in Table 2. However, the typical fund's return after 50 days (12.86 bps per bps surprise) is far greater than 5 times the 50-day response of the 6-year yield (approximately 7.5 basis points per bps surprise). This evidence suggests that Treasurys predominantly held by the typical mutual fund suffer larger price declines after a surprise rate increase. After 100 days, these funds are down 10.90 bps per 1 bps surprise, much larger than the 4.0 bps implied by the 5-year Treasury yield's response (0.8 bps.)

Mutual fund returns do not respond significantly to short rate surprises when the target rate does not change. Panel B and C break down the meeting days into days on which the target rate was unchanged and changed, respectively. Fifty days after the target rate change, a typical bond investor has lost 14.45 bps per one bps. surprise, which exceeds the implied estimate of 11.85 based on the response of the 5-year yield reported in Table 2. Clearly, as can be seen from Panel C, the results are entirely driven by target rate changes: Surprises have no significant impact on returns when the target rate does not change. Even on the day of impact, returns do not respond significantly to the size of the surprise. The explanatory power of these regressions is close to nil in the absence of a target change.

Table 6 provides a break-down of these return dynamics for different types of government bond funds. Intermediate Government Bond Funds invest in bonds with maturities from five to ten years. Short Government Bond Funds invest in bonds with maturities less than three years. Short/Intermediate Government bond funds invest in maturities between one and five years. After 50 days, intermediate funds have lost 11.80 bps per bps surprise, 9.08 bps for Intermediate/Short bond funds, and only 3.72 bps for the Short funds. Hence, for funds investing in Treasurys, the losses are monotonic in duration. However, the largest losses are recorded by TIPS funds: 13.99 bps.

Table 6: Impulse Response of U.S. Mutual Fund Returns

Panel A: No Target Changes						**Panel B: Target Changes**					
Short Government Bonds						*Short Government Bonds*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
-0.52	-1.96	0.59	-0.98	0.39	-6.35	-0.79	-1.28	-1.19	-1.36	-3.72	-3.30
[0.70]	[1.82]	[2.50]	[2.98]	[4.94]	[8.44]	[0.31]	[0.51]	[0.72]	[0.97]	[1.61]	[2.43]
(0.74)	(2.17)	(3.17)	(3.10)	(4.15)	(6.89)	(0.24)	(0.57)	(0.90)	(1.02)	(1.89)	(2.20)
0.01	0.03	0.00	0.00	0.00	0.01	0.13	0.13	0.06	0.05	0.11	0.04
Intermediate/Short Government Bonds						*Intermediate Short Government Bonds*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
-1.15	-4.44	-2.29	-5.54	-5.39	-6.16	-1.30	-2.99	-3.01	-3.15	-9.08	-9.22
[1.22]	[2.94]	[4.30]	[6.11]	[8.63]	[12.86]	[0.45]	[0.72]	[1.11]	[1.73]	[2.65]	[3.50]
(1.50)	(4.53)	(6.62)	(8.91)	(8.82)	(10.97)	(0.37)	(0.94)	(1.42)	(1.81)	(3.40)	(3.42)
0.02	0.06	0.01	0.02	0.01	0.01	0.17	0.30	0.15	0.08	0.22	0.14
Intermediate Government Bonds						*Intermediate Government Bonds*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
0.23	-5.92	-0.81	-4.51	4.21	-14.02	-1.15	-3.64	-3.70	-6.36	-11.80	-9.28
[1.50]	[4.18]	[5.68]	[8.18]	[11.16]	[18.40]	[0.59]	[0.98]	[1.49]	[2.54]	[3.78]	[4.59]
(1.45)	(5.64)	(7.57)	(8.84)	(8.68)	(17.32)	(0.59)	(1.02)	(1.57)	(3.12)	(4.78)	(3.94)
0.00	0.05	0.00	0.01	0.00	0.02	0.08	0.25	0.13	0.13	0.19	0.09
TIPS						*TIPS*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
-2.48	-7.91	-6.63	-18.13	-23.19	1.13	-1.68	-5.84	-5.12	-3.93	-13.99	-15.10
[2.30]	[5.37]	[7.94]	[13.17]	[20.70]	[23.42]	[0.74]	[1.63]	[1.82]	[2.81]	[3.59]	[4.63]
(2.74)	(7.55)	(12.85)	(22.59)	(33.35)	(23.32)	(0.61)	(2.12)	(1.97)	(3.27)	(4.18)	(5.14)
0.03	0.05	0.02	0.05	0.03	0.00	0.11	0.24	0.16	0.05	0.27	0.21

Impulse Response of U.S. mutual fund cumulative log returns to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. OLS (HAC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

Next, we exclude the log returns that are realized on the announcement day, and we run predictability regressions of cumulative log returns on the Kuttner innovation.

$$r^k_{\tau_i+1\to\tau_i+j-1} = a_{k,j} + b_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots. \quad (5)$$

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings. Panel A looks at no-target-change days. Panel B considers only target changes. After target changes, there is evidence of return predictability for longer maturity funds (Intermediate/Short, Intermediate and TIPS). The predictor variable is i.i.d.. The increase in R^2 at longer horizons is not an artefact of the predictor's persistence, and there is no Stambaugh bias in these slope coefficient estimates.

Table 7 reports the return predictability results. These results imply that mutual fund returns are indeed predictable by the surprise. Consider a 10 bps surprise, and let us abstract from the fact that one cannot short a mutual fund. These estimates imply that investors realize 73.6 bps in incremental return over 50 days by going long or short in these government bond funds or 3.68% per annum. The annualized return increases to 5.38% per annum for Intermediate Bond Funds (6.24% for TIPS). An R^2 of 0.15 implies that the maximum unconditional (annualized) Sharpe ratio increases from 0.48 to 0.98 (0.68) at the 50-day (100-day) horizon for a sophisticated investor.[7]

Table 7: Predicting U.S. Mutual Fund Returns

Panel A: No Target Changes						**Panel B: Target Changes**					
All Government Bonds						*All Government Bonds*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
-1.42	-4.40	-0.94	-10.40	-11.32	-3.82	-0.72	-1.86	-0.83	-2.64	-7.36	-8.10
[2.35]	[3.09]	[4.53]	[7.62]	[12.18]	[14.87]	[0.84]	[0.84]	[1.31]	[1.90]	[2.73]	[3.40]
(2.30)	(3.86)	(6.90)	(12.02)	(17.15)	(14.24)	(0.97)	(1.20)	(1.25)	(1.97)	(3.08)	(3.39)
0.01	0.05	0.00	0.05	0.02	0.00	0.02	0.11	0.01	0.04	0.15	0.12
Short Government Bonds						*Short Government Bonds*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
0.37	-1.18	2.44	-0.23	0.62	-5.84	-0.06	-0.35	-0.10	-1.37	-2.71	-2.51
[1.29]	[1.71]	[2.39]	[2.81]	[5.12]	[8.42]	[0.38]	[0.50]	[0.78]	[1.04]	[1.59]	[2.38]
(1.23)	(1.46)	(2.99)	(2.52)	(4.01)	(6.89)	(0.37)	(0.62)	(0.87)	(1.07)	(1.73)	(2.13)
0.00	0.01	0.03	0.00	0.00	0.01	0.00	0.01	0.00	0.04	0.07	0.03
Intermediate/Short Government Bonds						*Intermediate Short Government Bonds*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
0.04	-2.50	1.42	-4.79	-3.28	-5.00	-0.34	-1.32	-0.68	-2.94	-7.94	-7.92
[1.98]	[2.63]	[3.72]	[5.56]	[8.54]	[12.77]	[0.65]	[0.76]	[1.24]	[1.83]	[2.77]	[3.51]
(1.94)	(3.13)	(4.96)	(6.66)	(7.44)	(10.83)	(0.70)	(1.10)	(1.38)	(1.85)	(3.34)	(3.35)
0.00	0.02	0.00	0.02	0.00	0.00	0.01	0.07	0.01	0.06	0.17	0.11
Intermediate Government Bonds						*Intermediate Government Bonds*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
0.32	-4.65	2.27	-6.79	6.10	-14.25	-0.81	-2.14	-1.16	-6.55	-10.76	-8.13
[2.92]	[3.82]	[5.15]	[7.83]	[11.47]	[18.36]	[0.92]	[0.97]	[1.68]	[2.71]	[3.95]	[4.62]
(2.80)	(4.36)	(6.26)	(7.63)	(8.62)	(16.68)	(1.13)	(1.18)	(1.70)	(3.23)	(4.67)	(3.93)
0.00	0.04	0.01	0.02	0.01	0.02	0.02	0.11	0.01	0.12	0.15	0.07
TIPS						*TIPS*					
1	**5**	**10**	**20**	**50**	**100**	**1**	**5**	**10**	**20**	**50**	**100**
-1.88	-5.26	-2.39	-16.37	-18.41	3.62	-1.64	-3.46	-1.54	-4.00	-12.48	-13.42
[3.43]	[4.75]	[6.98]	[12.65]	[20.29]	[22.96]	[1.43]	[1.40]	[1.91]	[2.78]	[3.85]	[4.60]
(3.34)	(5.91)	(10.25)	(19.99)	(30.62)	(22.49)	(1.77)	(1.93)	(1.71)	(3.03)	(4.25)	(5.10)
0.01	0.03	0.00	0.04	0.02	0.00	0.03	0.13	0.02	0.05	0.20	0.17

Slope coefficient in regression of log U.S. mutual fund returns on 100 basis points (Kuttner) surprise in Federal Funds Rate: $r^k_{\tau_i+1\to\tau_i+j-1} = a_{k,j} + b_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots$. Forecasting of k-day ahead cumulative log returns. OLS (HAC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

Corporate bond funds display similar return dynamics. After a rate cut, corporate bond funds also experience losses that are increase over time in response to a surprise rate increase: after 50 days, the loss equals 9.46 bps per bps of surprise rate increase. However, the evidence after other FOMC meetings is decidedly mixed. We do not find similar dynamics in mortgage fund returns. These results are reported in Table A7 of the Appendix.

[7] The maximum unconditional Sharpe ratio is given by $\frac{\sqrt{SR^2_{bah}+\frac{R^2}{k}}}{\sqrt{1-R^2}}$, where SR_{bah} denotes the unconditional SR. We use an unconditional SR for 10-yr Treasurys of 0.408, based on Table 1 in Moskowitz, Ooi, and Pedersen (2012).

4.3 Mutual Fund Flows Dynamics

FOMC meetings are salient. News reporting about the FOMC and interest rates spikes around FOMC meetings. For example, Factiva reports that there were 166 news reports about the 'FOMC' and 'interest rates' per week in the Fall of 2017, but the numbers spikes to 659 (September FOMC meeting) and 396 (October/November FOMC meeting) in the weeks of the FOMC meetings.[8] Furthermore, more attention is devoted to FOMC meetings when the target rate is changed, especially around turning points for interest rate policy. Saliency plays an important role in accounting for the strong response of mutual fund flows to target changes.

In the CRSP sample, we only have monthly mutual fund flow and TNA data. In Oct. 2017, the government bond funds in the CRSP sample collectively manage \$257 bn in AUM. The corporate bond funds manage \$256 bn, while mortgage funds manage \$155 bn. There are other bond mutual funds not included in our sample that hold Treasuries (e.g. mixed bond-equity funds). We do not include municipal bond funds. Money market mutual funds manage over \$3 trillion.

Mutual fund flows respond sluggishly and persistently to the initial bond returns induced by short rate surprises generated, but only when these are accompanied by target changes. Surprise rate increases generate large mutual fund outflows when the target rate is changed for all fixed income funds, including government bonds, corporate bonds and mortgage funds. These effects are quantitatively significant. Figure 7 plots the impulse response of flows aggregated by type of bond fund, expressed as a fraction of aggregate TNA, in response to surprises when the target rate is not changed in Panel A, and when the target rate is changed in Panel B. Panel A shows that there is no statistically significant response of flows to the surprises when the target rate is not changed, except for government bond funds. For these funds, a positive surprise triggers inflows. However, as is clear from panel B, there is a strong negative response when the target rate is changed across all funds. Per bps. surprise, government bonds experience outflows of up to .5% of TNA per bps surprise, corporate bond funds up to .20% of TNA per bps surprise, and, finally, mortgage funds up to 1% per bps. The response of money market fund flows, as a fraction of TNA, is larger upon impact but does not build over time is and is completely transitory. As a result, there is a persistent shock to the supply of longer maturity assets when the Fed changes the target rate, but not to shorter dated assets.

[8] Results of a Factiva search for 'FOMC' and 'interest rates ' in the last 3 months in all sources, all authors, all companies, all subjects, all industries, all regions, in English.

Table 8 compares the responses on non-target-change (Panel A) and target-change FOMC meeting days (Panel B). If anything, when the target rate is not changed (Panel A), surprise rate increases lead to inflows for all fixed income funds, but the point estimates are not statistically different from zero, except for the case of government bond funds. The monetary surprises account for a much larger fraction for the variation in flows when the target rate is changed.

Table 8: Impulse Response of U.S. Mutual Fund Flows

Panel A: No Target Changes

Government Bonds					
1	**2**	**3**	**4**	**5**	**6**
0.16	0.27	0.36	0.44	0.49	0.61
[0.08]	[0.10]	[0.13]	[0.15]	[0.17]	[0.20]
(0.03)	(0.07)	(0.10)	(0.13)	(0.16)	(0.20)
0.04	0.07	0.08	0.09	0.08	0.09
Corporate Bonds					
1	**2**	**3**	**4**	**5**	**6**
0.04	0.09	0.10	0.12	0.18	0.19
[0.03]	[0.05]	[0.06]	[0.07]	[0.08]	[0.10]
(0.02)	(0.03)	(0.04)	(0.05)	(0.07)	(0.07)
0.02	0.03	0.03	0.03	0.05	0.04
Mortgages					
1	**2**	**3**	**4**	**5**	**6**
0.10	0.21	0.31	0.39	0.45	0.52
[0.16]	[0.18]	[0.23]	[0.28]	[0.30]	[0.35]
(0.04)	(0.06)	(0.09)	(0.11)	(0.13)	(0.16)
0.00	0.01	0.02	0.02	0.02	0.02
Money Market					
1	**2**	**3**	**4**	**5**	**6**
0.02	0.01	-0.03	0.04	-0.08	-0.08
[0.06]	[0.08]	[0.10]	[0.14]	[0.17]	[0.18]
(0.05)	(0.07)	(0.08)	(0.09)	(0.13)	(0.13)
0.00	0.00	0.00	0.00	0.00	0.00

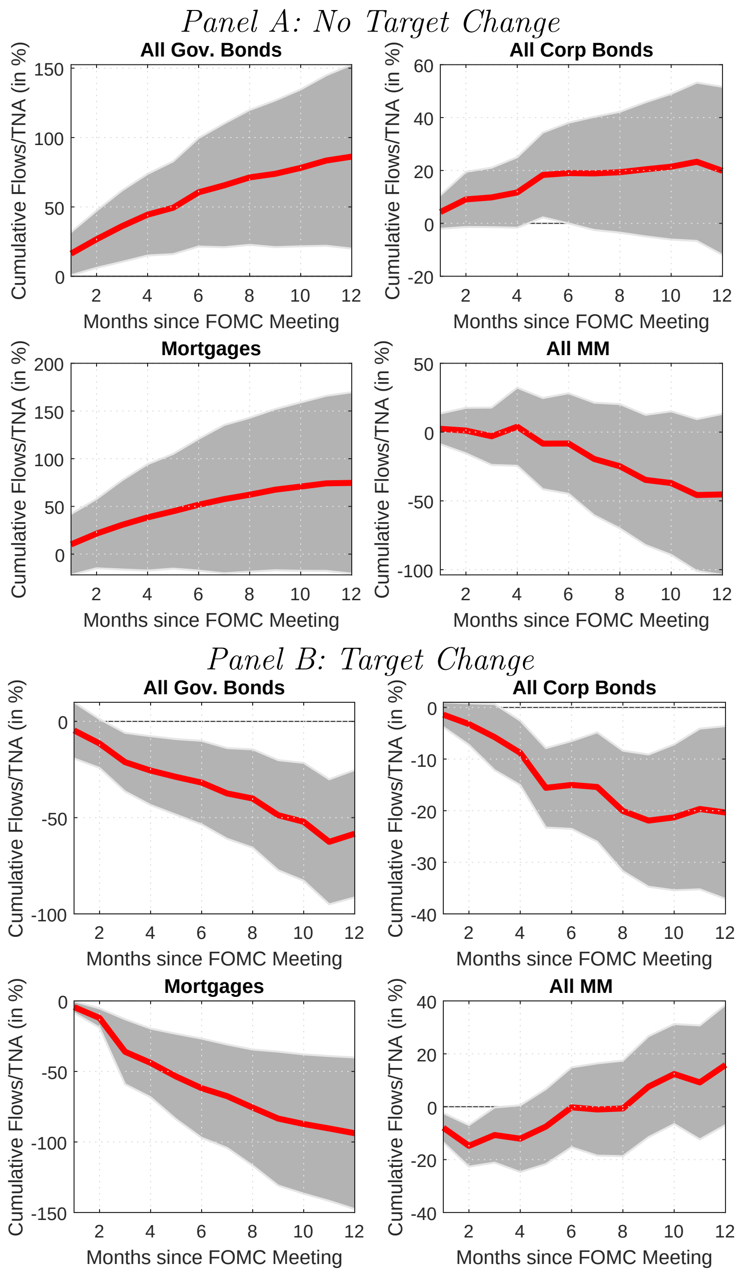
Panel B: Target Changes

Government Bonds					
1	**2**	**3**	**4**	**5**	**6**
-0.05	-0.11	-0.21	-0.26	-0.29	-0.32
[0.07]	[0.06]	[0.08]	[0.09]	[0.10]	[0.11]
(0.04)	(0.06)	(0.08)	(0.10)	(0.11)	(0.12)
0.01	0.05	0.12	0.13	0.13	0.13
Corporate Bonds					
1	**2**	**3**	**4**	**5**	**6**
-0.01	-0.03	-0.06	-0.09	-0.16	-0.15
[0.01]	[0.02]	[0.03]	[0.03]	[0.04]	[0.04]
(0.01)	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)
0.02	0.04	0.05	0.12	0.22	0.18
Mortgages					
1	**2**	**3**	**4**	**5**	**6**
-0.04	-0.12	-0.36	-0.44	-0.54	-0.62
[0.02]	[0.03]	[0.12]	[0.12]	[0.15]	[0.18]
(0.02)	(0.03)	(0.17)	(0.17)	(0.22)	(0.26)
0.07	0.19	0.15	0.19	0.18	0.18
Money Market					
1	**2**	**3**	**4**	**5**	**6**
-0.08	-0.15	-0.11	-0.12	-0.08	-0.00
[0.03]	[0.04]	[0.05]	[0.06]	[0.07]	[0.08]
(0.03)	(0.04)	(0.07)	(0.07)	(0.07)	(0.09)
0.13	0.20	0.07	0.06	0.02	0.00

Impulse Response of U.S. mutual fund flows to 100 basis points (Kuttner) surprise in Federal Funds Rate after k months. Aggregate Fund flows are divided by aggregate TNA. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008.

Panel A of Table 9 decomposes the fund flow responses for different types of government bond funds. There is strong evidence that mutual fund flows in and out of government bond funds mitigate the effects of Fed Funds surprises when the target rate is not changed. Panel B confirms that mutual fund investors amplify the effects of the monetary shocks when the target rate is changed. Table A8 in the separate appendix shows that these results continue to hold when we control for news about the path of future interest rates using Eurodollar deposit futures.

Figure 7: Impulse Response of U.S. Mutual Fund Flows: Target Changes



Impulse Response of U.S. mutual fund flows to 100 basis points (Kuttner) surprise in Federal Funds Rate after k months. Only target changes. Aggregate Fund flows are divided by aggregate TNA. Sample consists of all 161 FOMC meetings between 10/1/1982-10/29/2008.

Table 9: Impulse Response of U.S. Government Bond Mutual Fund Flows

Panel A: No Target Changes						**Panel B: Target Changes**					
Short Government Bonds						*Short Government Bonds*					
1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
0.23	0.33	0.47	0.59	0.68	0.84	-0.08	-0.18	-0.29	-0.40	-0.41	-0.46
[0.13]	[0.16]	[0.20]	[0.22]	[0.24]	[0.28]	[0.13]	[0.10]	[0.12]	[0.13]	[0.15]	[0.17]
(0.06)	(0.09)	(0.12)	(0.16)	(0.19)	(0.24)	(0.05)	(0.07)	(0.10)	(0.12)	(0.13)	(0.16)
0.03	0.04	0.06	0.07	0.08	0.09	0.01	0.06	0.09	0.13	0.12	0.12
Short/Intermediate Government Bonds						*Short/Intermediate Government Bonds*					
1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
0.19	0.36	0.55	0.69	0.78	0.93	-0.11	-0.24	-0.34	-0.44	-0.54	-0.61
[0.07]	[0.14]	[0.20]	[0.27]	[0.32]	[0.38]	[0.04]	[0.07]	[0.10]	[0.12]	[0.14]	[0.16]
(0.06)	(0.13)	(0.22)	(0.30)	(0.37)	(0.45)	(0.03)	(0.06)	(0.09)	(0.11)	(0.13)	(0.15)
0.08	0.07	0.08	0.07	0.06	0.07	0.13	0.19	0.19	0.20	0.22	0.22
Intermediate Government Bonds						*Intermediate Government Bonds*					
1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
0.08	0.19	0.23	0.29	0.26	0.33	-0.01	-0.02	-0.10	-0.08	-0.15	-0.15
[0.04]	[0.06]	[0.08]	[0.10]	[0.14]	[0.17]	[0.02]	[0.05]	[0.06]	[0.08]	[0.09]	[0.09]
(0.03)	(0.06)	(0.09)	(0.12)	(0.17)	(0.19)	(0.02)	(0.06)	(0.07)	(0.13)	(0.14)	(0.14)
0.05	0.10	0.08	0.08	0.04	0.04	0.00	0.00	0.05	0.02	0.05	0.04
TIPS						*TIPS*					
1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
0.22	0.41	0.49	0.62	0.76	0.82	0.01	-0.11	-0.22	-0.21	-0.23	-0.27
[0.06]	[0.12]	[0.17]	[0.22]	[0.27]	[0.31]	[0.05]	[0.09]	[0.11]	[0.14]	[0.17]	[0.19]
(0.05)	(0.10)	(0.14)	(0.19)	(0.26)	(0.32)	(0.05)	(0.09)	(0.11)	(0.14)	(0.15)	(0.17)
0.13	0.13	0.09	0.09	0.09	0.08	0.00	0.03	0.06	0.04	0.03	0.04

Impulse Response of U.S. mutual fund flows to 100 basis points (Kuttner) surprise in Federal Funds Rate after k months. Aggregate Fund flows are divided by aggregate TNA. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008.

Finally, Table A10 in the Appendix shows evidence suggesting that the quantitative response of mutual fund flows is almost entirely driven by the actual change in the target rate, not by the surprise itself, presumably because of the salience of the target change. The table reports the slope coefficients in a bivariate regression of fund flows on the surprise and the actual target rate change. This evidence is hard to square with rational investor behavior and lends support to the hypothesis that mutual investors destroy wealth by reallocating after an FOMC target change. Note that we can explain up to 50% of fund flow variation when we control for the size of the target change.

4.4 Bond Returns and Flows

Even in deep markets, demand curves slope down (see Shleifer, 1986; Mitchell, Pulvino, and Stafford, 2004; Coval and Stafford, 2007; Lou, Yan, and Zhang, 2013). A large literature investigates the effect of supply shocks in Treasury markets (Krishnamurthy, 2002; Han, Longstaff, and Merrill, 2007; Krishnamurthy and Vissing-Jorgensen, 2011, 2012; Swanson, 2011; Greenwood and Vayanos, 2014). Our paper contributes to this literature by estimating the elasticity of the demand for Treasurys using FOMC-induced exogenous variation in fund flows.

This section estimates the elasticity of demand for Treasurys. Table 10 reports the regression results obtained for all FOMC meetings. We run regressions of k-month cumulative mutual fund log returns on the mutual fund flows in the k months after the FOMC meeting. The $k = 1$ regression equation selects the month of the FOMC meeting. As a result, this is not a predictive regression. The panel on the left reports the OLS estimates. The panel on the right reports the IV estimate. The FOMC surprise creates exogenous variation in flows. We use the exogenous variation in the fund flows induced by all FOMC announcements. When we consider all government bonds funds, we find that a 10% outflow in excess of the mean induced by an FOMC meeting reduces the cumulative log return by 51.9 to 62.1 basis points over the following months. Given that mutual funds hold about 11% of the supply of government bonds, the elasticity of the Treasury prices with respect to supply is roughly 0.0051/0.011 or 0.44. We use an average duration of about 5 years. This duration implies that yields decrease by 10.38 to 12.42 basis points in response to a 10% outflow from government bond mutual funds. Hence, the semi-elasticity of yields is around 0.089.

The size of the effect depends on the maturity of the assets. For Short Government Bond (Short/Intermediate) funds, the estimates of the effects vary between 20.5 (27.1) and 24.3 (31.7) basis points. Finally, the estimates vary between 80.0 and 99.1 basis points for Intermediate Government Bond funds.

Table 10: Regression of Mutual Fund Returns on Fund Flows

Panel A: OLS in Announcement Months

All Government Bonds

1	**2**	**3**	**4**	**5**	**6**
-2.02	0.22	2.26	2.22	2.17	1.30
[1.76]	[1.77]	[0.96]	[0.64]	[0.58]	[0.39]
(1.50)	(1.81)	(0.63)	(0.70)	(0.69)	(0.40)
0.01	0.00	0.03	0.07	0.08	0.07

Short Government Bonds

1	**2**	**3**	**4**	**5**	**6**
-1.31	-0.26	0.78	2.27	4.20	4.09
[0.58]	[0.66]	[0.56]	[0.56]	[0.65]	[0.61]
(0.55)	(0.64)	(0.46)	(0.85)	(0.53)	(0.47)
0.03	0.00	0.01	0.10	0.21	0.22

Short/Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
6.79	6.08	5.53	4.57	4.93	4.44
[1.78]	[1.38]	[1.18]	[1.00]	[0.92]	[0.84]
(1.63)	(1.37)	(1.06)	(0.94)	(0.89)	(0.80)
0.09	0.12	0.13	0.13	0.17	0.16

Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
3.09	11.52	0.92	0.85	0.72	0.45
[5.50]	[4.00]	[0.45]	[0.31]	[0.29]	[0.18]
(6.86)	(5.42)	(0.19)	(0.14)	(0.14)	(0.11)
0.00	0.05	0.03	0.05	0.04	0.04

TIPS

1	**2**	**3**	**4**	**5**	**6**
10.71	10.18	11.11	8.99	8.76	8.03
[3.72]	[3.07]	[2.49]	[2.02]	[1.76]	[1.68]
(4.88)	(2.65)	(2.08)	(1.92)	(1.57)	(1.32)
0.06	0.07	0.12	0.12	0.15	0.14

Panel B: IV in all Months

All Government Bonds

1	**2**	**3**	**4**	**5**	**6**
6.21	5.44	4.91	4.96	5.19	5.38
[3.08]	[2.42]	[2.04]	[1.85]	[1.74]	[1.65]
(2.85)	(2.09)	(1.81)	(1.58)	(1.38)	(1.26)
0.02	0.02	0.02	0.03	0.03	0.04

Short Government Bonds

1	**2**	**3**	**4**	**5**	**6**
2.09	2.07	2.05	2.16	2.30	2.43
[1.42]	[1.16]	[1.02]	[0.95]	[0.91]	[0.88]
(1.34)	(1.03)	(0.90)	(0.81)	(0.74)	(0.70)
0.01	0.01	0.02	0.02	0.02	0.03

Short/Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
3.17	2.85	2.71	2.77	2.91	3.00
[1.29]	[1.07]	[0.94]	[0.87]	[0.82]	[0.79]
(1.17)	(0.94)	(0.84)	(0.75)	(0.67)	(0.62)
0.02	0.03	0.03	0.04	0.05	0.05

Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
9.91	9.10	7.75	7.79	8.09	8.43
[4.95]	[4.19]	[3.68]	[3.42]	[3.27]	[3.17]
(4.57)	(3.81)	(3.48)	(3.22)	(2.96)	(2.71)
0.02	0.02	0.02	0.02	0.02	0.03

TIPS

1	**2**	**3**	**4**	**5**	**6**
14.79	13.10	10.77	10.05	12.43	14.99
[11.32]	[9.87]	[8.97]	[8.53]	[8.42]	[8.39]
(12.05)	(10.37)	(9.29)	(8.76)	(8.74)	(8.11)
0.01	0.01	0.01	0.01	0.01	0.01

Time Series Regression of k-month Mutual Fund Returns on Mutual Fund Flows in month after FOMC meeting. Monthly cumulative log returns in months after FOMC meeting, including the month of the meeting. Returns expressed in pps. Aggregate Fund flows are divided by aggregate TNA. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The sample contains 59 Fed Funds Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008.

Mutual fund investors distort long rates in the wake of FOMC announcements. Fed Funds target rate changes trigger large, gradual flows out of or into fixed income funds that cannot be readily absorbed by other market participants.

5 Dynamic Response of Treasury Yields: Robustness

There are three concerns that we address in this section. First, our estimated impulse response function might be biased up because news about the future path is released on the same day. That news may be correlated with the shocks to the Fed Funds rate. Second, the regression windows overlap. Given that the Fed Funds rate surprised are weakly correlated, we may be picking up the effects of a future surprise at the next FOMC meeting that are included. We also control for news on days when the Fed minutes are released. Third, news about macro-variables may be released if the FOMC has access to private information about macro variables.

5.1 Dynamic Response to News about Future Interest Rates

The response of long maturity bonds to monetary policy innovations seems puzzlingly large. During FOMC meetings, new information about the path of future interest rate is typically revealed. This release of new information may bias the slope coefficients upwards, because it contributes to correlation between the innovations to yields –the residuals in our regression equation–and the Fed Funds rate surprises. To mitigate this, we control for new information about the path of future interest rates by including the change in the price of Eurodollar futures on the FOMC meeting day (see Gürkaynak, Sack, and Swanson, 2007, for a motivation of the use of Eurodollar futures). We include the 4-quarter and 8-quarter contracts. These futures will reveal news about changes in the path of future interest rates.

To compute the impulse responses, we run regressions of cumulative yield changes between $t-1$ and $t+j-1$ on the monetary policy surprise at t, as well as the news about the future path of the Fed Funds rate revealed on the same day:

$$y^k_{\tau_i+j-1} - y_{\tau_i-1} = a_{k,j} + \beta_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \gamma_{4,j}(f^4_{\tau_i} - f^4_{\tau_i-1}) + \gamma_{8,j}(f^8_{\tau_i} - f^8_{\tau_i-1}) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots. \quad (6)$$

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings. Under the null of efficient markets and rational expectations, these Δr^u_t are i.i.d. over time and uncorrelated with the residuals $\varepsilon^{k,j}_{t+j}$. Under these conditions, the OLS estimator is unbiased and consistent.

Table 11 reports the detailed results. Panel A looks at FOMC meeting days without target rate changes. The initial impact varies from 44 basis points for 3-month bonds to 29 basis points for bonds with 1-year maturity. These regressions which includes news about the path of interest rates account for more than 70% of the overall variation on the FOMC meeting day. For shorter maturities, that fraction is closer to 90%, suggesting that the Fed Funds futures adequately capture news about the path of future interest rates. For the 1-year bond, the impulse-response increases to 135 basis points after 50 days. Panel B looks at the FOMC meeting days on which the target rate was changed. After 50 days, these impulse responses are all larger than 200 basis points, except for bonds with maturities in excess of 10 years, even though the initial impact is less than 50 basis points for all bonds. The point estimates are quite similar (See Figure A1 in Appendix.).

When there was no target change, we note the largest effect of controlling for the path. Without controls, these estimated impulse responses were significantly negative for short-term bonds. After controlling for news about the path, that is no longer the case. The impulse responses after target changes look similar to the ones obtained without the controls.

To make sense of this finding, consider a simple example. Suppose that investors expected a 25 basis point increase going into the FOMC meeting, but the Fed decided not to change the target rate at the FOMC meeting. This is a negative interest rate surprise: the Fed funds rate is 25 basis lower than investors expected. However, the Fed could signal that it would increase the Fed Funds rate target by 50 bps at the next FOMC meetings. In this case, bond yields might actually increase. The regression of yield changes only on current Kuttner surprises yields a negative coefficient at longer horizons, but this effect disappears when we control for news about the path by including future changes.

Table 11: Impulse Response of U.S. Treasuries on FOMC Meeting Days

Panel A: No Target Changes

	1	5	10	20	50	100
3 MTH	0.46	0.80	0.73	0.99	1.84	2.33
	[0.05]	[0.10]	[0.15]	[0.22]	[0.36]	[0.64]
	(0.07)	(0.10)	(0.16)	(0.23)	(0.33)	(0.64)
	0.69	0.51	0.28	0.25	0.30	0.17
6 MTH	0.42	0.75	0.76	1.01	1.80	2.15
	[0.03]	[0.09]	[0.13]	[0.21]	[0.38]	[0.64]
	(0.05)	(0.10)	(0.12)	(0.20)	(0.32)	(0.63)
	0.82	0.55	0.38	0.27	0.28	0.15
1 YR	0.37	0.68	0.73	0.92	1.62	1.78
	[0.03]	[0.09]	[0.13]	[0.22]	[0.38]	[0.63]
	(0.05)	(0.10)	(0.10)	(0.19)	(0.31)	(0.60)
	0.86	0.52	0.36	0.24	0.25	0.11
2 YR	0.20	0.36	0.46	0.49	1.02	0.83
	[0.04]	[0.12]	[0.14]	[0.24]	[0.40]	[0.63]
	(0.05)	(0.12)	(0.11)	(0.18)	(0.31)	(0.59)
	0.83	0.29	0.22	0.13	0.16	0.04
3 YR	0.15	0.32	0.33	0.33	0.91	0.45
	[0.03]	[0.11]	[0.14]	[0.24]	[0.41]	[0.62]
	(0.04)	(0.12)	(0.11)	(0.17)	(0.31)	(0.55)
	0.88	0.31	0.18	0.09	0.14	0.02
5 YR	0.09	0.20	0.23	0.14	0.69	0.11
	[0.03]	[0.10]	[0.13]	[0.24]	[0.39]	[0.55]
	(0.05)	(0.11)	(0.11)	(0.18)	(0.31)	(0.44)
	0.87	0.30	0.13	0.07	0.11	0.01
7 YR	0.04	0.13	0.16	0.06	0.61	0.02
	[0.03]	[0.10]	[0.14]	[0.23]	[0.37]	[0.50]
	(0.05)	(0.10)	(0.12)	(0.19)	(0.29)	(0.38)
	0.87	0.32	0.12	0.06	0.11	0.01
10 YR	0.00	0.07	0.07	-0.03	0.53	-0.03
	[0.03]	[0.10]	[0.13]	[0.22]	[0.35]	[0.46]
	(0.04)	(0.09)	(0.11)	(0.19)	(0.30)	(0.37)
	0.83	0.29	0.13	0.06	0.09	0.01
20 YR	-0.04	-0.02	0.06	-0.03	0.41	-0.07
	[0.03]	[0.10]	[0.12]	[0.20]	[0.31]	[0.39]
	(0.04)	(0.09)	(0.11)	(0.19)	(0.27)	(0.31)
	0.73	0.24	0.13	0.03	0.09	0.00
30 YR	-0.06	-0.06	-0.03	-0.14	0.42	-0.17
	[0.03]	[0.10]	[0.12]	[0.19]	[0.29]	[0.38]
	(0.04)	(0.09)	(0.10)	(0.19)	(0.26)	(0.30)
	0.63	0.17	0.09	0.02	0.09	0.01

Panel B: Target Changes

	1	5	10	20	50	100
3 MTH	0.45	0.71	0.91	1.14	2.02	2.85
	[0.08]	[0.16]	[0.27]	[0.40]	[0.69]	[1.26]
	(0.11)	(0.16)	(0.26)	(0.45)	(0.58)	(0.86)
	0.57	0.32	0.19	0.14	0.21	0.11
6 MTH	0.36	0.57	0.81	1.12	2.13	2.79
	[0.05]	[0.15]	[0.23]	[0.39]	[0.72]	[1.28]
	(0.06)	(0.15)	(0.24)	(0.42)	(0.56)	(0.90)
	0.81	0.39	0.24	0.17	0.21	0.10
1 YR	0.30	0.60	0.86	1.12	2.42	2.75
	[0.05]	[0.16]	[0.23]	[0.40]	[0.72]	[1.25]
	(0.05)	(0.17)	(0.25)	(0.41)	(0.56)	(0.91)
	0.85	0.43	0.28	0.16	0.23	0.09
2 YR	0.16	0.48	0.76	0.82	2.19	2.05
	[0.05]	[0.20]	[0.27]	[0.46]	[0.77]	[1.25]
	(0.06)	(0.21)	(0.27)	(0.41)	(0.58)	(0.95)
	0.87	0.34	0.21	0.10	0.19	0.05
3 YR	0.12	0.46	0.59	0.72	2.24	1.71
	[0.05]	[0.19]	[0.27]	[0.48]	[0.77]	[1.22]
	(0.07)	(0.20)	(0.24)	(0.42)	(0.60)	(0.92)
	0.88	0.35	0.18	0.09	0.19	0.04
5 YR	0.06	0.39	0.62	0.73	2.18	1.37
	[0.04]	[0.18]	[0.27]	[0.48]	[0.73]	[1.08]
	(0.06)	(0.21)	(0.24)	(0.48)	(0.65)	(0.90)
	0.89	0.34	0.18	0.10	0.19	0.03
7 YR	-0.04	0.32	0.47	0.66	2.06	1.03
	[0.04]	[0.17]	[0.28]	[0.46]	[0.70]	[0.99]
	(0.07)	(0.21)	(0.24)	(0.49)	(0.64)	(0.82)
	0.89	0.34	0.13	0.09	0.17	0.02
10 YR	-0.05	0.26	0.37	0.64	2.03	0.99
	[0.04]	[0.18]	[0.27]	[0.45]	[0.68]	[0.92]
	(0.06)	(0.22)	(0.21)	(0.52)	(0.71)	(0.86)
	0.86	0.25	0.11	0.07	0.16	0.02
20 YR	-0.12	0.24	0.40	0.56	1.72	0.77
	[0.05]	[0.18]	[0.25]	[0.40]	[0.60]	[0.79]
	(0.08)	(0.22)	(0.22)	(0.45)	(0.52)	(0.63)
	0.75	0.19	0.12	0.05	0.16	0.03
30 YR	-0.12	0.21	0.30	0.41	1.56	0.33
	[0.05]	[0.19]	[0.24]	[0.38]	[0.56]	[0.77]
	(0.07)	(0.23)	(0.23)	(0.45)	(0.59)	(0.73)
	0.65	0.14	0.09	0.03	0.14	0.03

Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

5.2 Serial correlation in Monetary Surprises

Under the null of efficient markets, the Kuttner surprises should be i.i.d. over time, but there is some evidence of negative serial correlation in these surprise measures. Table 12 reports predictability regressions for monetary surprises. We regress future surprises at the next meeting, or the meeting after that, on current FOMC meeting day surprises:

$$\begin{aligned}\left(-\Delta r^u_{\tau_{i+1}}\right) &= a_{k,j} + \beta_{k,j}\left(-\Delta r^u_{\tau_i}\right) + e_{\tau_i}, j = 1, 2, \ldots \\ \left(-\Delta r^u_{\tau_{i+2}}\right) &= a_{k,j} + \beta_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \gamma_{k,j}\left(-\Delta r^u_{\tau_{i+1}}\right) + e_{\tau_i}, j = 1, 2, \ldots\end{aligned}$$

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings;

Table 12: Forecasting Monetary Surprises

Panel A: No Target Changes			**Panel B: Target Changes**			**Panel C: All FOMC Meetings**		
	1st	**2nd**		**1st**	**2nd**		**1st**	**2nd**
	0.35	0.09		0.18	-0.01		0.21	0.01
	[0.16]	[0.18]		[0.09]	[0.07]		[0.08]	[0.09]
	(0.15)	(0.23)		(0.10)	(0.08)		(0.09)	(0.09)
	0.05	0.02		0.07	0.17		0.05	0.05
Nobs	98.00	98.00	**Nobs**	58.00	57.00	**Nobs**	156.00	155.00

Forecasting the monetary policy surprise at the next (subsequent) FOMC meeting with the current surprise. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains 157 regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008.

There is some evidence of predictability. Autocorrelation in the predictors could bias our coefficient estimates. The slope coefficient is statistically significantly different from zero in the case of no target changes, and when we consider all FOMC meetings. The estimated slope coefficients are economically large; they vary between 0.18 and 0.35.

To guard against the effects of serial correlation in monetary surprises, we include the actual surprise on the next two FOMC meetings or surprises due to inter-meeting rate changes on the right hand side, provided that they happen during the event window. To compute the impulse responses, we run regressions of cumulative yield changes between $t-1$ and $t+j-1$ on the monetary policy surprise at t:

$$\begin{aligned}y^k_{\tau_i+j-1} - y_{\tau_i-1} &= a_{k,j} + \beta_{k,j}\left(-\Delta r^u_{\tau_i}\right) \\ &+ \delta^1_{k,j}\left(-\Delta r^u_{\tau_{i+1}}\right)\mathbb{I}_{\tau_{i+1}<j} + \delta^2_{k,j}\left(-\Delta r^u_{\tau_{i+2}}\right)\mathbb{I}_{\tau_{i+2}<j} + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots.\end{aligned}$$

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings; We report results for $k = 50$, keeping only those observations for which we have another FOMC meeting within the 50 day window. We also report results for $k = 100$, keeping those observations for which we have another two FOMC meetings within the 100 window.

Table A11 in the appendix reports the results for $k = 50, 100$. In Panel A of Table A11, we report the results for FOMC meetings days without a target rate change. Clearly, the dynamic response of yields to monetary surprises has shifted upwards relative to the benchmark case. However, the standard errors on these slope coefficient estimates are quite large. In Panel B, we report results for FOMC meeting days on which the target rate has been changed. The slope coefficient estimates on the monetary surprises have increased slightly relative to the benchmark case. For the 1-year yield, the point estimates are 3.02 (2.81) at the 50 (100)-day mark. These estimates are statistically significantly different from zero. Conditional on a target rate change, the next surprise at τ_{i+1} ends to negatively correlated with the surprise on the event day τ_i. In Panel C, we include all FOMC meetings; the effect of negative serial correlation is mitigated.

In addition, we also control for news about the path. We include the actual surprise on the next two FOMC meetings on the right hand side, provided that they happen during the event window. To compute the impulse responses, we run regressions of cumulative yield changes between $t-1$ and $t+j-1$ on the monetary policy surprise at t:

$$\begin{aligned} y^k_{\tau_i+j-1} - y_{\tau_i-1} &= a_{k,j} + \beta_{k,j}\left(-\Delta r^u_{\tau_i}\right) \\ &+ \gamma_{4,j}(f^4_{\tau_i} - f^4_{\tau_i-1}) + \gamma_{8,j}(f^8_{\tau_i} - f^8_{\tau_i-1}) \\ &+ \delta^1_{k,j}\left(-\Delta r^u_{\tau_{i+1}}\right)\mathbb{I}_{\tau_{i+1}<j} + \delta^2_{k,j}\left(-\Delta r^u_{\tau_{i+2}}\right)\mathbb{I}_{\tau_{i+2}<j} + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots. \end{aligned}$$

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings; We report results for $k = 50$, keeping only those observations for which we have another FOMC meeting within the 50 day window. We also report results for $k = 100$, keeping those observations for which we have another two FOMC meetings within the 100 window. Table A12 in the Appendix reports the results for $k = 50, 100$. The results are in line with the other results.

Finally, Table A13 in the Appendix reports the response of Treasury yields to monetary surprises when controlling for the release of the Fed minutes that occur in the window, while Table A14 in the Appendix reports the response of Treasury yields when controlling for surprises on FOMC meeting days that occur in the window and the release of the Fed minutes.

5.3 Changes in Macro-economic Expectations

Finally, another possible explanation is that news is released around the FOMC meeting that causes agents to revise their expectations about future economic fundamentals (e.g. inflation, GDP growth).

We use the change in the Blue Chip Financial Forecasts around the FOMC meeting to control for changes in expectations. Every month, the BCFF uses a panel of experts who submit their expectations for GDP growth and inflation for the next 5 quarters and the current one. The survey occurs between the 23-rd and 26-th of the preceding month. The January survey occurs between the 17-th and 21-th of December. We look for the first survey date after the FOMC meeting, and we use the one-month change in expectations $\Delta\mathbb{F}^l_{\tau_i}(x)$ relative to the previous month as our controls. We use either all of the changes in GDP forecasts or all of the changes in inflation forecasts as our controls:

$$y^k_{\tau_i+j-1} - y_{\tau_i-1} \quad = \quad a_{k,j} + \beta_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \sum_l \gamma^l_{k,j}\Delta\mathbb{F}^l_{\tau_i}(x) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots.$$

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings; $\Delta\mathbb{F}^l_{\tau_i}(x)$ is the change in expectations around the FOMC meeting on date τ_i. Table A15 in the Appendix reports the response of the forecasts to the monetary surprises. $\Delta\mathbb{F}^l_{\tau_i+j-1}(x)$ is the j-month change after the FOMC meeting. We can only use 97 FOMC meetings. We report the slope coefficients in regression of $\Delta\mathbb{F}^l_{\tau_i+j-1}(x)$ on the monetary surprise. There is a strong contemporaneous response of the change in expectations about GDP in Q1 (current quarter) and Q2. For example, after target changes, a 100 basis point Fed Funds surprise leads to an immediate 251 (182) basis point increase in the expected growth rate of real GDP for Q1 (Q2). When there are no target changes, a 100 basis point Fed Funds surprise leads to an immediate 227 (178) basis point increase in the expected growth rate of real GDP for Q1 (Q2), consistent with the findings of Nakamura and Steinsson (2013). This expectations effect could be immediate feedback from the Fed's decisions to changes in expectations of the survey participants, if the Fed has access to private information about the U.S. economy, or it could reflect feedback from changes in expectations not fully reflected in Fed Funds futures prices to the Fed's decisions. Monetary surprises on FOMC meeting days account for between 16% (4%) and 41% (21%) of the changes in Q1 GDP forecasts.

Table 13 reports the estimated impulse responses controlling for revisions in expected GDP growth. The changes in expectations of future GDP growth around FOMC meetings increase the explanatory power of these regressions at the 50-day horizon, especially for the longer maturities. The regressions now accounts for about 1/4th of the variation in bond yields with maturities in excess of 10 years. However, the point estimates for the impulse response are even higher than before. The evidence for sluggish adjustment or initial under-reaction is even stronger. The 50-day impact estimate for the 10-year yield has increased from 141 bps. to 291 bps. Table A16 in the appendix considers target changes separately. As before, the evidence for sluggish adjustment is much stronger following target changes. Finally, Table A17 in the appendix checks the results obtained when controlling for changes in expected inflation. Our results are robust to controlling for changes in expected inflation.

Table 13: Impulse Response of U.S. Treasuries on FOMC Meeting Days: Controlling for GDP Expectations

	1	**5**	**10**	**20**	**50**	**100**
3 MTH	0.37	0.57	0.35	0.10	0.93	0.97
	[0.09]	[0.24]	[0.46]	[0.46]	[0.84]	[1.57]
	(0.15)	(0.33)	(0.49)	(0.50)	(0.84)	(1.43)
	0.22	0.14	0.10	0.16	0.14	0.11
6 MTH	0.58	0.67	0.46	0.40	1.19	1.32
	[0.08]	[0.19]	[0.28]	[0.43]	[0.85]	[1.57]
	(0.09)	(0.23)	(0.29)	(0.49)	(0.80)	(1.50)
	0.41	0.25	0.17	0.18	0.16	0.12
1 YR	0.50	0.79	0.49	0.46	1.92	1.96
	[0.09]	[0.21]	[0.27]	[0.43]	[0.85]	[1.54]
	(0.10)	(0.29)	(0.35)	(0.48)	(0.84)	(1.54)
	0.28	0.24	0.17	0.15	0.17	0.12
2 YR	0.46	0.67	0.37	0.63	2.33	2.43
	[0.14]	[0.25]	[0.31]	[0.52]	[0.93]	[1.57]
	(0.14)	(0.29)	(0.38)	(0.56)	(1.01)	(1.71)
	0.16	0.23	0.17	0.09	0.14	0.11
3 YR	0.41	0.68	0.27	0.62	2.43	2.42
	[0.14]	[0.25]	[0.32]	[0.56]	[0.95]	[1.55]
	(0.14)	(0.27)	(0.33)	(0.60)	(1.12)	(1.77)
	0.15	0.21	0.10	0.07	0.14	0.11
5 YR	0.32	0.72	0.52	1.07	2.78	2.60
	[0.13]	[0.26]	[0.32]	[0.56]	[0.87]	[1.40]
	(0.11)	(0.29)	(0.33)	(0.70)	(1.02)	(1.53)
	0.17	0.17	0.11	0.09	0.17	0.11
7 YR	0.20	0.73	0.58	1.18	2.77	2.04
	[0.12]	[0.25]	[0.32]	[0.54]	[0.80]	[1.28]
	(0.10)	(0.27)	(0.33)	(0.72)	(0.93)	(1.44)
	0.15	0.16	0.09	0.09	0.18	0.08
10 YR	0.13	0.65	0.62	1.49	2.91	2.21
	[0.10]	[0.25]	[0.31]	[0.52]	[0.73]	[1.14]
	(0.08)	(0.29)	(0.35)	(0.69)	(0.87)	(1.21)
	0.14	0.13	0.08	0.13	0.23	0.10
20 YR	-0.00	0.44	0.61	1.16	2.13	1.24
	[0.09]	[0.24]	[0.28]	[0.43]	[0.61]	[0.93]
	(0.08)	(0.28)	(0.28)	(0.56)	(0.72)	(1.00)
	0.13	0.09	0.10	0.12	0.23	0.08
30 YR	-0.02	0.52	0.56	1.05	2.05	0.59
	[0.08]	[0.23]	[0.28]	[0.42]	[0.58]	[0.93]
	(0.09)	(0.28)	(0.29)	(0.47)	(0.61)	(1.09)
	0.14	0.10	0.09	0.11	0.26	0.10

Impulse Response of U.S. Treasuries with Constant Maturity to 100 basis points (Kuttner) surprise in Federal Funds Rate after k days. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). Full sample contains only 97 regularly scheduled FOMC meetings in the 1-Feb-1994 and 29-Oct-2008. HAC (Newey-West, Bartlett kernel) standard errors computed with bandwidth of 2 for $k < 50$, 3 for $50 \geq k < 75$ and 4 for $k \geq 75$.

6 Conclusion

Recently, more attention has been paid to the institutional details of money markets (see, e.g., Duffie and Krishnamurthy, 2016) and local banking markets (see, e.g., Drechsler, Savov, and Schnabl, 2017) to better understand how monetary policy is transmitted to the real economy. Our work points to an important role for fixed income mutual funds in monetary policy transmission. Fed Funds target rate changes are particularly potent in affecting long rates because their salience triggers a large response from performance-chasing mutual fund investors, whereas forward guidance does not. Our findings suggest that mutual funds may play a key role in the transmission of monetary policy to Treasury, corporate bond and mortgage markets. This deserves further research on the role of delegated asset management in fixed income in monetary policy transmission.

Our paper also sheds new light on the excess sensitivity of long yields to short rates, the excess volatility of bonds in general, and the sources of time-series momentum in bond markets.

References

Berk, Jonathan B., and Richard C. Green, 2004, Mutual fund flows and performance in rational markets, *Journal of Political Economy* 112, 1269–1295.

Bernanke, Ben S., and Kenneth N. Kuttner, 2005, What explains the stock market's reaction to federal reserve policy?, *The Journal of Finance* 60, 1221–1257.

Bernard, Victor L., and Jacob K. Thomas, 1989, Post-earnings-announcement drift: Delayed price response or risk premium?, *Journal of Accounting Research* 27, 1–36.

Chan, Louis K. C., Narasimhan Jegadeesh, and Josef Lakonishok, 1996, Momentum strategies, *The Journal of Finance* 51, 1681–1713.

Chevalier, Judith, and Glenn Ellison, 1997, Risk taking by mutual funds as a response to incentives, *Journal of Political Economy* 105, 1167–1200.

Cieslak, Anna, 2018, Short-rate expectations and unexpected returns in treasury bonds, *The Review of Financial Studies* 31, 3265–3306.

Cochrane, John H., and Monika Piazzesi, 2002, The fed and interest rates - a high-frequency identification, *American Economic Review* 92, 90–95.

Cook, Timothy, and Thomas Hahn, 1989, The effect of changes in the federal funds rate target on market interest rates in the 1970s, *Journal of Monetary Economics* 24, 331 – 351.

Coval, Joshua, and Erik Stafford, 2007, Asset fire sales (and purchases) in equity markets, *Journal of Financial Economics* 86, 479 – 512.

Dellavigna, Stefano, and Joshua Pollet, 2009, Investor inattention and friday earnings announcements, *The Journal of Finance* 64, 709–749.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl, 2017, The deposits channel of monetary policy, *The Quarterly Journal of Economics* 132, 1819–1876.

Duffee, Gregory R., 2018, Expected inflation and other determinants of treasury yields, *The Journal of Finance* 0.

Duffie, Darrell, 2010, Presidential address: Asset price dynamics with slow-moving capital, *The Journal of Finance* 65, 1237–1267.

——— , and Arvind Krishnamurthy, 2016, Passthrough efficiency in the fed's new monetary policy setting, in *Designing Resilient Monetary Policy Frameworks for the Future. Federal Reserve Bank of Kansas City, Jackson Hole Symposium.*

Falato, Antonio, Ali Hortacsu, Dan Li, and Chaehee Shin, 2016, Fire-sale spillovers in debt markets, .

Fedyk, Anastassia, 2017, Front page news: The effect of news positioning on financial markets, Discussion paper, Working paper, Harvard University.

Fleckenstein, Matthias, Francis A. Longstaff, and Hanno Lustig, 2014, The tips-treasury bond puzzle, *The Journal of Finance* 69, 2151–2197.

Gertler, Mark, and Peter Karadi, 2015, Monetary policy surprises, credit costs, and economic activity, *American Economic Journal: Macroeconomics* 7, 44–76.

Greenwood, Robin, 2008, Excess comovement of stock returns: Evidence from cross-sectional variation in nikkei 225 weights, *The Review of Financial Studies* 21, 1153–1186.

——— , and David Thesmar, 2011, Stock price fragility, *Journal of Financial Economics* 102, 471 – 490.

Greenwood, Robin, and Dimitri Vayanos, 2014, Bond supply and excess bond returns, *The Review of Financial Studies* 27, 663–713.

Gürkaynak, Refet S., Brian Sack, and Eric Swanson, 2005a, The sensitivity of long-term interest rates to economic news: Evidence and implications for macroeconomic models, *American Economic Review* 95, 425–436.

Gürkaynak, Refet S, Brian Sack, and Eric T Swanson, 2005b, Do actions speak louder than words? the response of asset prices to monetary policy actions and statements, *International Journal of Central Banking.*

Gürkaynak, Refet S, Brian P Sack, and Eric T Swanson, 2007, Market-based measures of monetary policy expectations, *Journal of Business & Economic Statistics* 25, 201–212.

Han, Bing, Francis A. Longstaff, and Craig Merrill, 2007, The u.s. treasury buyback auctions: The cost of retiring illiquid bonds, *The Journal of Finance* 62, 2673–2693.

Hanson, Samuel Gregory, David O. Lucca, and Jonathan H. Wright, 2017, Interest rate conundrums in the twenty-first century, .

Hanson, Samuel G., and Jeremy C. Stein, 2015, Monetary policy and long-term real rates, *Journal of Financial Economics* 115, 429 – 448.

Hirshleifer, David, Sonya Seongyeon Lim, and Siew Hong Teoh, 2018, Driven to distraction: Extraneous events and underreaction to earnings news, *The Journal of Finance* 64, 2289–2325.

Krishnamurthy, Arvind, 2002, The bond/old-bond spread, *Journal of Financial Economics* 66, 463 – 506 Limits on Arbitrage.

——— , and Annette Vissing-Jorgensen, 2007, The demand for treasury debt, Working Paper 12881 National Bureau of Economic Research.

——— , 2011, The effects of quantitative easing on interest rates: Channels and implications for policy [with comments and discussion], *Brookings Papers on Economic Activity* pp. 215–287.

——— , 2012, The aggregate demand for treasury debt, *Journal of Political Economy* 120, 233–267.

Kuttner, Kenneth N, 2001, Monetary policy surprises and interest rates: Evidence from the fed funds futures market, *Journal of Monetary Economics* 47, 523 – 544.

Lou, Dong, Hongjun Yan, and Jinfan Zhang, 2013, Anticipated and repeated shocks in liquid markets, *The Review of Financial Studies* 26, 1891–1912.

Mitchell, Mark, Todd Pulvino, and Erik Stafford, 2004, Price pressure around mergers, *The Journal of Finance* 59, 31–63.

Moskowitz, Tobias J., Yao Hua Ooi, and Lasse Heje Pedersen, 2012, Time series momentum, *Journal of Financial Economics* 104, 228 – 250 Special Issue on Investor Sentiment.

Nakamura, Emi, and Jón Steinsson, 2013, High frequency identification of monetary non-neutrality: The information effect, Working Paper 19260 National Bureau of Economic Research.

———, 2018, High-frequency identification of monetary non-neutrality: The information effect*, *The Quarterly Journal of Economics* 133, 1283–1330.

Piazzesi, Monika, and Eric T. Swanson, 2008, Futures prices as risk-adjusted forecasts of monetary policy, *Journal of Monetary Economics* 55, 677 – 691.

Rigobon, Roberto, and Brian Sack, 2004, The impact of monetary policy on asset prices, *Journal of Monetary Economics* 51, 1553 – 1575.

Rudebusch, Glenn D., 1998, Do measures of monetary policy in a var make sense?, *International Economic Review* 39, 907–931.

Savor, Pavel, and Mungo Wilson, 2014, Asset pricing: A tale of two days, *Journal of Financial Economics* 113, 171 – 201.

Shleifer, Andrei, 1986, Do demand curves for stocks slope down?, *The Journal of Finance* 41, 579–590.

Sirri, Erik R., and Peter Tufano, 1998, Costly search and mutual fund flows, *The Journal of Finance* 53, 1589–1622.

Swanson, Eric T, 2011, Let's twist again: a high-frequency event-study analysis of operation twist and its implications for qe2, *Brookings Papers on Economic Activity* 2011, 151–188.