Post-FOMC Announcement Drift in U.S. Bond Markets

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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 Federal Funds target changes contributes to the excess sensitivity of long rates. Mutual fund investors respond to the salience of Federal Funds target rate increases by selling short and intermediate duration bond funds, thus gradually increasing the effective supply to be absorbed by arbitrageurs. The gradual increase in supply generates post-announcement drift in longer Treasury yields, which spills over to other bond markets. Our findings shed new light on the causes of time-series-momentum in bond markets. A model in which mutual fund investors slowly adjust their extrapolative expectations of future short rates after a target change can qualitatively match the dynamics of yields and fund flows.

Keywords: Yield Curve, Term Structure, Monetary Policy.

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1 Introduction

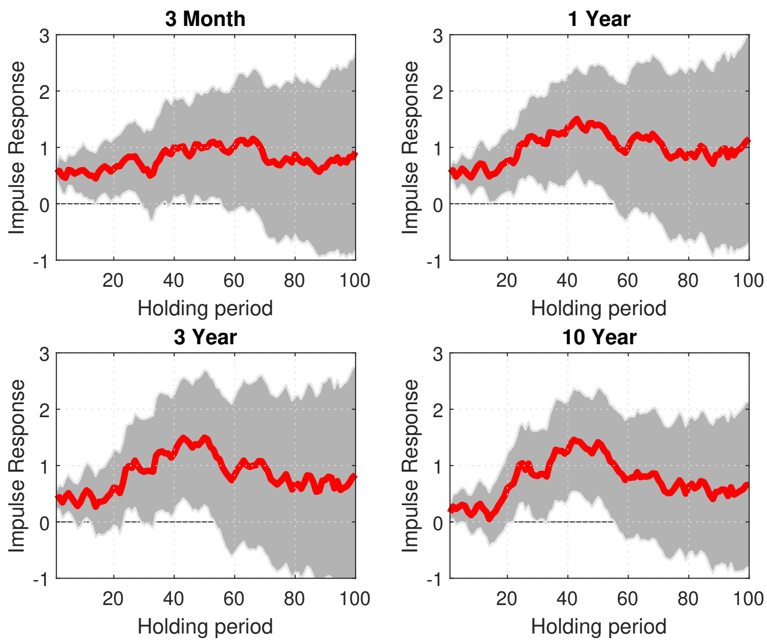
Long-term nominal and real rates co-vary strongly with short-term rates (Cochrane and Piazzesi, 2002; Gürkaynak, Sack, and Swanson, 2005a; Hanson and Stein, 2015; Hanson, Lucca, and Wright, 2017). Gürkaynak, Sack, and Swanson (2005a) dubbed this the excess sensitivity of long rates. The sensitivity of long rates 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 (Duffee, 2018).

Our paper demonstrates that there is post-FOMC (Federal Open Market Committee) announcement drift in bond markets, which contributes to the puzzling relation between short and long rates. Figure 1 plots the IRF (Impulse Response Function) of Treasury yields to surprises in the FFR (Federal Funds Rate). Treasury yields at longer maturities initially respond sluggishly to FFR surprises. The same-day response of 10-year Treasury yields to a 10 bps. surprise in the FFR 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 FF target rate was raised. 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. 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 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.

We find direct evidence that these deviations from the expectations hypothesis are due to price pressure. After FF 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 ac-

Figure 1: IRF of U.S. Treasurys: All Regularly Scheduled FOMC Meetings



IRF of U.S. Treasurys in bps with Constant Maturity to 1 bps (Kuttner) surprise in FFR 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$k \leq 50$.

tually raises the Fed Fund target rate. Target rate changes are more salient to mutual fund investors. Within a year, mutual funds collectively sell 5.4% of their Treasury holdings per 10 basis points positive surprise. We also find evidence that banks and GSEs eventually also sell a significant amount of Treasurys.

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), we show that these effects are due to mostly to positive surprises, and we show that the response of government bond mutual fund returns to the FF 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 FF 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, 2018a). 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.

After a surprise rate increase, a typical bond fund experiences negative fund returns on the FOMC announcement day. In response to these exogenously induced 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. While it may be rational for 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.

To account for the joint dynamics in yields and mutual fund flows, we develop a model in which mutual fund investors have sticky expectations and extrapolate when forecasting future short rates. When the Fed raises rates, extrapolative investors overestimate future FFR, and as a result, mutual fund investors sell Treasurys, because they anticipate an increase in long yields. Extrapolative expectations about future macro-economic variables emerge naturally when investors run regressions with a limited number of regressors, which will lead them to overestimate the persistence of macro-economic conditions (Fuster, Laibson, and Mendel, 2010; Fuster, Hebert, and Laibson, 2011). Cieslak (2018) demonstrates that survey forecasts of the FFR put too much weight on the current short rate, when compared against statistical forecasts. Mutual fund investors' expectations inherit those extrapolative characteristics.

2 Related Literature

There is a growing body of survey-based evidence which suggests that bond investors make systematic mistakes when they forecast future short rates. These forecast errors can impute return predictability to bond returns that is orthogonal to the subjective risk premia that investors demand (see Piazzesi and Schneider, 2011; Cieslak, 2018, for recent examples). Our paper contributes to this literature by showing that fixed income mutual fund flows are consistent with fund investors who systematically overestimate the path of future short rates after the Fed raises the short rate.

To match the slow response of mutual fund investors, we consider a model in which mutual fund bond investors have sticky and extrapolative short rate expectations. After an FF target change, only a fraction of mutual fund investors update their information set on any given day (Mankiw and Reis, 2002). Our model is similar to the one used by Katz, Lustig, and Nielsen (2017) to account for the slow response of stock prices to inflation news. Consistent with this sticky expectations hypothesis, Coibion and Gorodnichenko (2015) document evidence of information stickiness in inflation expectation surveys that is economically significant.

In our model, mutual fund investors overweight the current short rate when developing beliefs, consistent with Cieslak (2018)'s findings, thus extrapolating the fundamentals (Barberis, Shleifer, and Vishny, 1998; Fuster, Laibson, and Mendel, 2010; Fuster, Hebert, and Laibson, 2011). Since there is no underlying cash flow risk in our setting, this is equivalent to return extrapolation (Hong and Stein, 1999; Barberis and Shleifer, 2003; Greenwood and Shleifer, 2014; Barberis, Greenwood, Jin, and Shleifer, 2015).

There is a large literature that documents excess volatility for long-dated assets including stocks and bonds going back to the seminal work by LeRoy and Porter (1981); Shiller (1981); Campbell and Shiller (1988). More recently, Stein (1989) documents overreaction in long-dated option prices. Giglio and Kelly (2017) show that the volatility of longer maturity claims is too large relative to that of that short-dated claims to the same cash flows. In various derivatives and bond markets, the longer maturity prices seem to ignore the mean reversion in the underlying cash flows. Finally, Gürkaynak, Sack, and Swanson (2005a) show that long-run Treasury yields are too sensitive to macroeconomic announcements. Our findings identify a similar maturity puzzle in the excessive response of long yields to FOMC announcements, and we suggest a mechanism that can help explain this phenomenon.

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, but this mechanism only applies to salient target rate increases that were not priced in by the market. Thus, our findings raise additional questions about the external validity of studies that use these shocks to identify the effect of monetary policy on real outcomes (see Nakamura and Steinsson, 2018b, for a discussion of the information channel and implications for external vailidity).

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.

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 this interpretation does not extend to FOMC surprises. 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, 2017, for more recent work).

The rest of the paper is organized as follows. Section 3 describes the response of yields in the frictionless benchmark model. Section 4 explains how we use monetary surprises in the data, and estimates the dynamic impulse response of Treasury yields to surprises in the FFR. Section 5 describes the response of bond mutual fund returns and mutual fund flows to FFR surprises, and we estimate the elasticity of the demand for Treasurys. Section 6 describes a model in which mutual fund investors have sticky and extrapolative expectations. Section 7 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 FF surprises and the release of the Fed's minutes. Our main findings do not change.

3 Pass-Through of Short Rate News to Long Yields

High-frequency identification of the effects of monetary policy shocks 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 FF 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. To set a frictionless benchmark for the pass-through of short rate news to long yields, we consider the simplest version of the rational expectations hypothesis.

When the FOMC meets, bond investors revise their forecasts of the short rate. By iterating forward on the nominal bond return equation expressed in logs, we obtain the following expression for the log yield on an N-maturity zero coupon bond as a function of future log returns:

$$y_t^N \equiv \frac{1}{N}\left[\sum_{j=1}^{N} r_{t+j}^{N-j+1}.\right] \tag{1}$$

This expression has to hold for all sample paths. Investors use this nominal pricing equation to value the bonds, which gives rise to the following yield expectation under their subjective measure:

$$y_t^N = \frac{1}{N}\mathbb{E}_t^*\left[\sum_{j=1}^{N} r_{t+j}^{N-j+1}.\right] \tag{2}$$

Put differently, the yield is the sum of expected short rates, $r_t^{\$}$, and log bond risk premia, rx_t^N:

$$y_t^N = \frac{1}{N}\mathbb{E}_t^*\left[\sum_{j=1}^{N} rx_{t+j}^{N-j+1}\right] + \frac{1}{N}\mathbb{E}_t^*\left[\sum_{j=1}^{N} r_{t+j-1}^{\$}\right].$$

FOMC surprises should mainly affect the second component because these reveal news about short rates. In that case, the expectations hypothesis seems like reasonable starting point. We start by imposing that the expectations hypothesis holds. If the expectations hypothesis holds, the expected return on the long bond equals the short rate period by period: $\mathbb{E}_t^* r_{t+j}^{N-j+1} = \mathbb{E}_t^* r_{t+j-1}^{\$}$ and the yield desired by the investor equals:

$$y_t^N = \frac{1}{N}\mathbb{E}_t^*\left[\sum_{j=1}^{N} r_{t+j-1}^{\$}.\right] \tag{3}$$

In our benchmark model, investors are endowed with rational expectations. Rational expectations investors use the actual data generating process for the short rate when they update: $r_{t+1}^{\$} = (1-\phi)\theta + \phi r_t^{\$} + u_{t+1}$. The rational expectations yield instantaneously reflects news about the short yield:

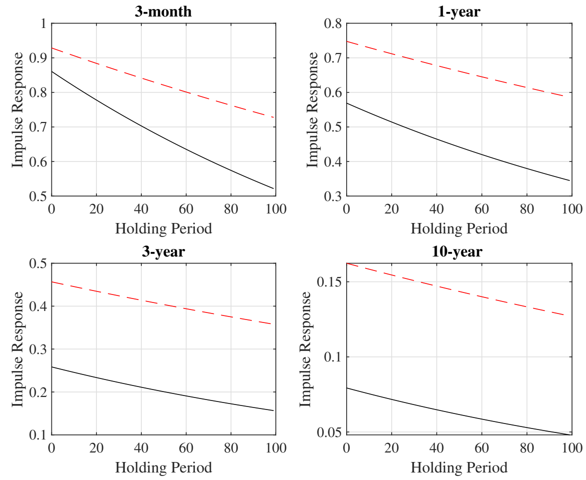
$$(y_t^{N,RE} - \theta) = \frac{1}{N}\frac{1-\phi^N}{1-\phi}(r_t^{\$} - \theta).$$

As can easily be verified, the IRF for nominal yields in our benchmark model is given by:

$$\frac{\Delta y_{t+k}^{N,RE}}{\Delta r_t^{\$}} = \frac{1}{N}\frac{1-\phi^N}{1-\phi}\phi^k.$$

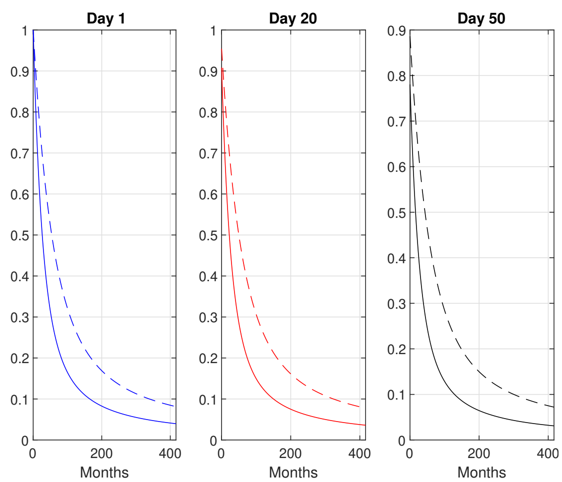
Figure 2 plots the IRF in the benchmark model for the 3-month yield, the 1-year yield, the 3-year yield and the 10-year yield. Yields instantaneously adjust to the news about the short rate. As the short rate reverts back to the mean, yields decline. The full (dashed) line plots the case in which the monthly persistence of the short rate is 0.90 (0.95). The IRFs shift down as we increase the maturity of the zero coupon bonds. The response is strongest at the short end of the maturity spectrum. As we consider longer maturity bonds, the IRF shifts down. As the persistence of the short rate increases, the impact on long yields increases significantly. For example, upon impact, the 10-year yield increases by more than 16 bps after a 100 bps shock. Figure 3 plots the term structure of yield responses to a 100 bps shock after 1 days, after 20 days and after 50 days. Maturity is on the horizontal axis. The term structure is steeply downward sloping and shifts down over time.

Figure 2: IRF of Yields–Expectations Hypothesis



Response in bps to 1 bps shock. ϕ=0.9 (full line) and ϕ=0.95 (dotted line).

Figure 3: Term Structure of Yield Responses–Expectations Hypothesis



Response in bps to 1 bps shock. Response in bps. Maturity of bonds on horizontal axis. We plot the response for monthly persistence of the short rate ϕ=0.9 (bottom line) and ϕ=0.95 (top line).

Even when the expectations hypothesis does not hold, eqn. (3) holds under the risk-neutral measure in the absence of arbitrage opportunities. If short rates follow a mean-reverting process under the risk-neutral measure, then the same equation describes yields: $(y_t^{N,RE} - \theta) = \frac{1}{N}\frac{1-\phi^{N,*}}{1-\phi_*}(r_t^{\$} - \theta)$, where ϕ^* is the mean-reversion parameter under the risk-neutral measure. This benchmark model cannot reproduce the impulse responses of yields in the data, especially at longer maturities. In section 6, we develop a sticky version of the expectations hypothesis: in our model, mutual fund investors have sticky, extrapolative expectations when they evaluate the forecast of future short rates in eqn. (3) to price longer bonds.

4 Dynamic IRF of Yields to News about Short Rate

4.1 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, 2018a; 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 FF futures prices in a short window. Typically, researchers have used the nearest FF futures contract to extract the surprise shock to the FF 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 FF target rates can be extracted from Eurodollar deposit contracts with longer tenors (Gürkaynak, Sack, and Swanson, 2005b, 2007; Nakamura and Steinsson, 2018a).

We use FF 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:

$$\Delta r_t^u = \left(f_t^0 - f_{t-1}^0\right)\frac{m}{m-t}. \tag{4}$$

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 FFR.[1]

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 FFR 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 FF 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) surprises around (non-)target change FOMC meetings. There are 59 recorded changes in the FF 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,

[1]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.

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.

We exclude inter-meeting rate changes from the baseline sample, because these are different. The FOMC decides to change the rate in response to new information that has emerged on that day. In fact, a few of the early instances coincide with the release of the employment report. In this time period, there are a total of 25 inter-meeting rate changes. These inter-meeting changes tend to generate larger surprises. The standard deviation of the surprises on these days is 17 bps, and it includes a number of outliers, like the 71 bps surprise in January of 2008. Only 2 of these are rate increases. The average surprise is -18 bps.

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 FFR. 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 FF Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. The pre-crisis sample contains 51 FF target changes between 5-June-1989 and 09-May-2007. The post-1994 sample contains 53 FOMC meetings after 22-Dec-1993.

4.2 Bond 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.

4.3 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:

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

where $\tau_i \in \tau$ is the date of one of the regularly scheduled FOMC meetings. 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, 2018a).[2] Instead, we will use a longer event window to study the response of yields. 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 $\varepsilon^{k,j}_{t+j}$.[3] 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 FF 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

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

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

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 7. There is recent evidence that investors do revise their expectations about future fundamentals (Nakamura and Steinsson, 2018a) in response to monetary surprises, which could feed back into bond risk premia. We control for these effects in section 7. 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.

4.4 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 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. 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.

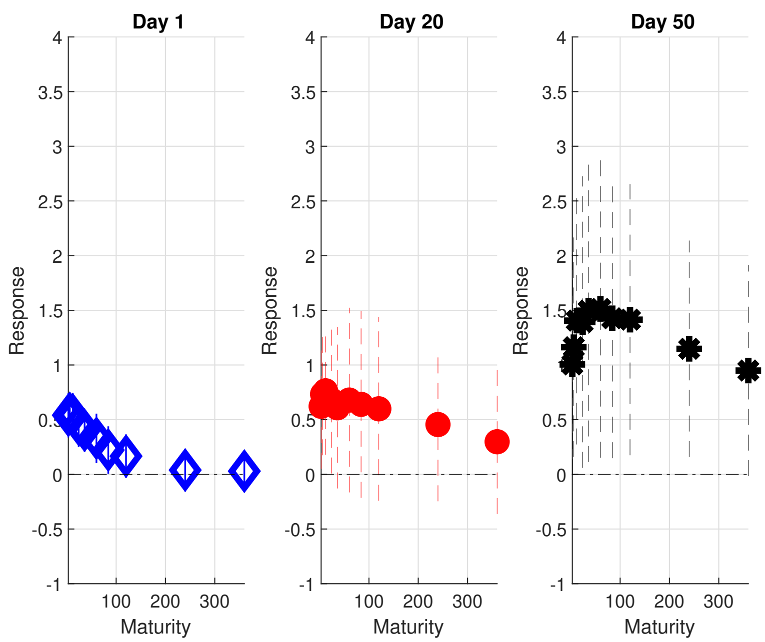
Table 2: IRF of U.S. Treasury Yields

	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

IRF in bps. of U.S. Treasurys with Constant Maturity to 1 bps (Kuttner) surprise in FFR 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 FF 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 4 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 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.

Figure 4: Term Structure of U.S. Treasury Responses: All FOMC Meetings



IRF of U.S. Treasurys in bps with Constant Maturity to 1 bps (Kuttner) surprise in FFR after k days. Maturity of bonds on horizontal axis. 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 $k \leq 50$.

It is natural to assume that the expectations hypothesis holds for monetary surprises. We can then compare these responses to the responses in the benchmark (rational) expectations hypothesis model in section 3 (see Figure 2 and 3). If we compare the initial impact across maturities, then the one-day response of the one-year bond (54 bps) is consistent with a monthly persistence in the short rate of 0.90. The response of the 10-year bond (0.17) bps is consistent with a monthly persistence closer to 0.95: 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). Upon impact, the term structure of responses is strongly downward sloping (see Figure 4), consistent with the expectations hypothesis.

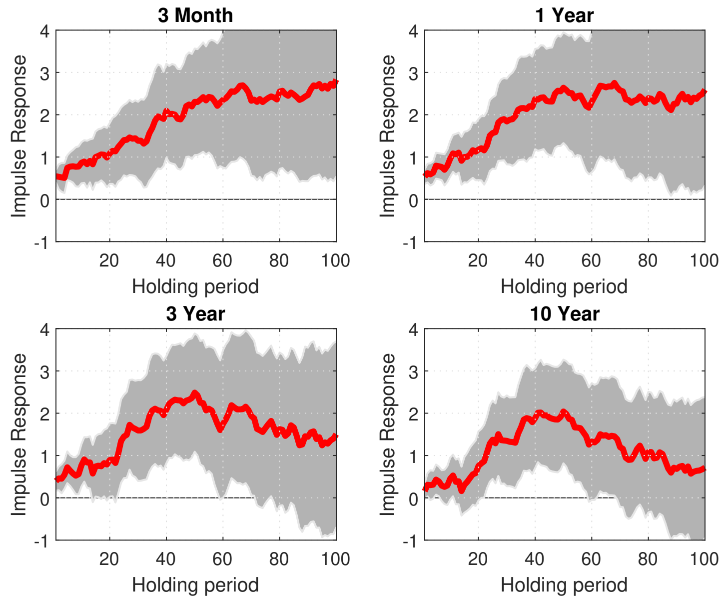
To summarize, the expectations hypothesis seems to approximately hold on FOMC meeting days, consistent with the findings of Savor and Wilson (2014), but not thereafter. After 20 days, the term structure of responses is still downward sloping, but we need an even higher monthly persistence of 0.995 to match the 10-year yield's response (60 bps) to the 1-year response (76 bps). 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.

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 FFR 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 FFR 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.

4.5 Changes in the FF Target Rate

These effects are entirely driven by changes in the FF 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 5 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

Figure 5: IRF of U.S. Treasurys: Target Changes

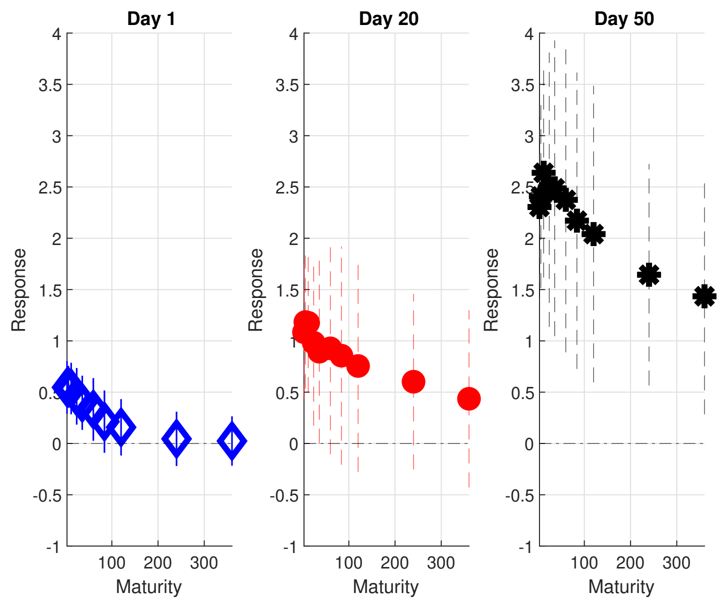


IRF of U.S. Treasurys in bps. with Constant Maturity to 1 bps. (Kuttner) surprise in FFR after k days. Full sample contains 59 FF Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008. HAC standard errors computed with one lag for $k \leq 50$.

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 6 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 6: IRF of U.S. Treasurys: Target Changes



IRF in bps. of U.S. Treasurys with Constant Maturity to 1 bps. (Kuttner) surprise in FFR after k days. Full sample contains 59 FF 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: IRF of U.S. Treasurys 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

IRF in bps of U.S. Treasurys with Constant Maturity to1 bps. (Kuttner) surprise in FFR 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 FF 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 FF 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 FFR. 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 FFR, 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 report the results obtained when all rate changes, including the inter-meeting changes, are included in Table A4 in the Appendix. This approach is more standard in 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.[4] When we include the inter-meeting changes, the post-FOMC announcement drift is considerably weaker. This attenuation occurs largely because the 26 additional target changes induce large surprises, but only 2 are rate increases. The post-announcement drift is almost entirely due to surprise rate increases, as shown in Table 4 which only considers positive surprises. The panel on the left includes the inter-meeting changes. The panel on the right does not. After 50 days, the 10-year yield increases by as much as 47 to 48 basis points in response to a 10 bps positive surprise; this effect is more than twice as large as the effect of all surprises when the rate is changed. The impulse response for negative surprises is small and does not show drift. This asymmetry is consistent with our fund-flow induced price pressure hypothesis.

[4]In fact, before 1994, some of these meetings coincided exactly with the release of the Employment report. In these instances, the FF target rate change was triggered directly by the release.

Table 4: IRF of U.S. Treasurys to Positive Rate Surprises

Panel A: Excluding Inter-Meeting Changes						
	1	**5**	**10**	**20**	**50**	**100**
1 MTH	-1.31	-1.46	0.53	-1.78	1.34	-1.38
	[0.53]	[0.60]	[0.62]	[1.48]	[2.29]	[4.16]
	(1.22)	(1.21)	(0.23)	(0.91)	(1.65)	(1.93)
	0.27	0.26	0.04	0.08	0.02	0.01
3 MTH	0.10	0.28	0.29	0.20	2.12	1.78
	[0.18]	[0.34]	[0.61]	[0.88]	[1.70]	[2.85]
	(0.32)	(0.22)	(0.40)	(0.71)	(1.45)	(2.67)
	0.01	0.02	0.01	0.00	0.05	0.01
6 MTH	0.32	0.33	-0.02	0.88	2.40	2.19
	[0.19]	[0.31]	[0.51]	[0.89]	[1.75]	[2.93]
	(0.19)	(0.36)	(0.37)	(0.77)	(1.41)	(2.80)
	0.09	0.03	0.00	0.03	0.06	0.02
1 YR	0.37	0.39	0.20	1.33	3.26	2.88
	[0.21]	[0.39]	[0.44]	[0.90]	[1.67]	[2.77]
	(0.24)	(0.47)	(0.39)	(0.79)	(1.28)	(2.55)
	0.09	0.03	0.01	0.07	0.11	0.03
2 YR	0.46	0.61	0.51	2.13	4.56	3.44
	[0.28]	[0.47]	[0.48]	[0.99]	[1.66]	[2.56]
	(0.42)	(0.60)	(0.44)	(0.75)	(1.45)	(2.23)
	0.08	0.05	0.04	0.13	0.20	0.05
3 YR	0.40	0.72	0.66	2.34	5.11	3.61
	[0.28]	[0.46]	[0.46]	[1.00]	[1.58]	[2.40]
	(0.42)	(0.57)	(0.52)	(0.84)	(1.56)	(2.11)
	0.06	0.07	0.06	0.15	0.25	0.07
5 YR	0.31	0.80	0.84	2.31	5.07	3.05
	[0.28]	[0.47]	[0.47]	[1.00]	[1.44]	[2.12]
	(0.42)	(0.52)	(0.60)	(0.98)	(1.57)	(1.93)
	0.04	0.09	0.09	0.15	0.28	0.06
7 YR	0.22	0.74	0.74	2.20	4.81	2.73
	[0.28]	[0.44]	[0.50]	[0.96]	[1.36]	[1.94]
	(0.45)	(0.46)	(0.66)	(1.00)	(1.54)	(1.86)
	0.02	0.09	0.07	0.15	0.29	0.06
10 YR	0.13	0.58	0.74	2.10	4.32	2.28
	[0.24]	[0.43]	[0.48]	[0.91]	[1.27]	[1.82]
	(0.39)	(0.37)	(0.65)	(1.02)	(1.53)	(1.85)
	0.01	0.05	0.07	0.14	0.27	0.05
20 YR	0.00	0.63	0.86	1.86	3.63	2.04
	[0.20]	[0.39]	[0.46]	[0.80]	[1.11]	[1.57]
	(0.32)	(0.28)	(0.59)	(0.90)	(1.44)	(1.75)
	0.00	0.08	0.10	0.15	0.26	0.05
30 YR	-0.01	0.60	0.84	1.82	3.44	1.84
	[0.19]	[0.42]	[0.46]	[0.76]	[1.03]	[1.53]
	(0.31)	(0.32)	(0.57)	(0.83)	(1.23)	(1.68)
	0.00	0.06	0.10	0.16	0.26	0.04

Panel B: Including Inter-Meeting Changes						
	1	**5**	**10**	**20**	**50**	**100**
1 MTH	-1.31	-1.46	0.53	-1.78	1.34	-1.38
	[0.53]	[0.60]	[0.62]	[1.48]	[2.29]	[4.16]
	(1.22)	(1.21)	(0.23)	(0.91)	(1.65)	(1.93)
	0.27	0.26	0.04	0.08	0.02	0.01
3 MTH	0.19	0.37	0.46	0.53	2.39	2.22
	[0.20]	[0.34]	[0.61]	[0.91]	[1.66]	[2.74]
	(0.33)	(0.22)	(0.40)	(0.78)	(1.45)	(2.66)
	0.03	0.03	0.02	0.01	0.06	0.02
6 MTH	0.42	0.43	0.15	1.28	2.67	2.53
	[0.20]	[0.32]	[0.53]	[0.94]	[1.70]	[2.81]
	(0.23)	(0.35)	(0.39)	(0.87)	(1.43)	(2.75)
	0.12	0.05	0.00	0.05	0.07	0.02
1 YR	0.46	0.46	0.38	1.68	3.48	3.13
	[0.22]	[0.40]	[0.50]	[0.94]	[1.62]	[2.65]
	(0.25)	(0.44)	(0.39)	(0.86)	(1.32)	(2.49)
	0.12	0.04	0.02	0.09	0.12	0.04
2 YR	0.54	0.62	0.60	2.37	4.66	3.56
	[0.28]	[0.47]	[0.49]	[0.98]	[1.58]	[2.45]
	(0.42)	(0.58)	(0.44)	(0.80)	(1.49)	(2.15)
	0.10	0.05	0.04	0.15	0.21	0.06
3 YR	0.50	0.72	0.73	2.54	5.11	3.63
	[0.28]	[0.46]	[0.48]	[0.99]	[1.51]	[2.30]
	(0.42)	(0.57)	(0.52)	(0.89)	(1.60)	(2.07)
	0.09	0.07	0.07	0.17	0.26	0.07
5 YR	0.42	0.76	0.86	2.46	5.00	3.01
	[0.29]	[0.45]	[0.45]	[0.97]	[1.37]	[2.04]
	(0.43)	(0.52)	(0.60)	(1.01)	(1.59)	(1.90)
	0.06	0.08	0.10	0.16	0.29	0.06
7 YR	0.33	0.66	0.74	2.33	4.73	2.66
	[0.29]	[0.43]	[0.48]	[0.92]	[1.29]	[1.87]
	(0.46)	(0.48)	(0.66)	(1.04)	(1.56)	(1.84)
	0.04	0.07	0.07	0.16	0.29	0.06
10 YR	0.23	0.52	0.75	2.21	4.26	2.26
	[0.25]	[0.41]	[0.47]	[0.88]	[1.21]	[1.75]
	(0.40)	(0.38)	(0.63)	(1.03)	(1.50)	(1.84)
	0.02	0.04	0.07	0.16	0.27	0.05
20 YR	0.09	0.55	0.82	1.91	3.59	2.07
	[0.21]	[0.38]	[0.44]	[0.77]	[1.08]	[1.52]
	(0.34)	(0.29)	(0.57)	(0.92)	(1.41)	(1.76)
	0.01	0.06	0.10	0.16	0.26	0.06
30 YR	0.07	0.52	0.81	1.89	3.42	1.87
	[0.20]	[0.40]	[0.44]	[0.72]	[0.99]	[1.49]
	(0.32)	(0.33)	(0.56)	(0.85)	(1.19)	(1.68)
	0.00	0.05	0.09	0.17	0.26	0.05

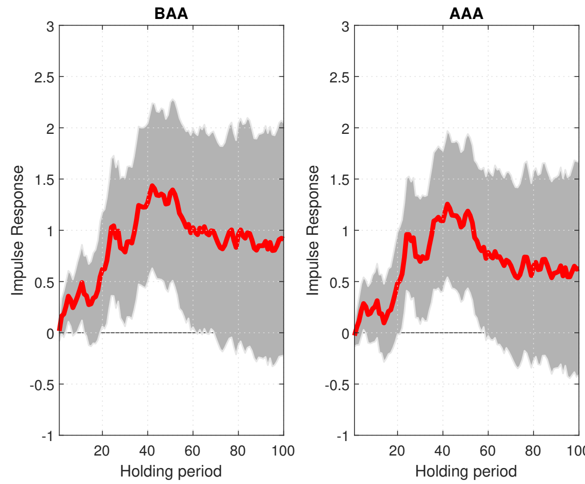
IRF in bps. of U.S. Treasurys with Constant Maturity to 1 bps. (Kuttner) positive surprise in FFR after k days. OLS (HC) standard errors in parentheses (brackets) reported on row (2) and (3) of each panel. The unadjusted R^2 is reported in row (4). The sample contains 35 positive surprises due to FF 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 $k \geq 75$.

4.6 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 A5 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 7 plots the impulse-responses for corporate bond yields. The

Figure 7: IRF of U.S. Corporate Bond Yields



IRF in bps. of U.S. Corporate Yields to 1 bps. (Kuttner) surprise in FFR 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 $k \geq 75$.

panel on the left (right) plots the impulse response for BAA (AAA) bonds. In the case of 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 A6 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 A7 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 FF futures since FF futures settle to an average FFR 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.

5 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 $14.933 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 $1111.5 billion in Treasurys and T-Bills. Money market mutual funds hold another $728.6 bn in Treasurys and T-bills (Source: Federal Flow of Funds, Table L 210). Mutual funds hold another $ 641 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 $641 bn in agency and GSE-backed securities. Another $146.7 bn is held in ETFs. (source: U.S. Federal Flow of Funds. 2017.Q2). This means that U.S. mutual and money market funds hold about 13.30% 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.

5.1 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 Fuds (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 Institutional Money Market Funds (IMM), Institutional Tax-Exempt Money Market Funds (ITE), Institutional U.S. Treasury Money Market Funds (ITM), Institutional 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.

5.2 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 FFR 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:

$$r^k_{\tau_i \to \tau_i+j-1} = a_{k,j} + b_{k,j} \left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i+j-1}, j = 1, 2, \ldots . \quad (6)$$

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

Table 5: IRF 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

Panel D: Target Changes and Positive Surprises

1	5	10	20	50	100
-3.98	-9.72	-12.38	-22.26	-28.33	-14.59
[1.54]	[3.38]	[2.92]	[5.71]	[8.59]	[8.85]
(1.32)	(2.54)	(1.97)	(4.96)	(6.69)	(9.34)
0.22	0.26	0.43	0.39	0.31	0.10

IRF of U.S. government bond mutual fund cumulative log returns in percentage points to 100 basis points (Kuttner) surprise in FFR 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 (33) FF Target Changes (that induce positive surprises) 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.

These effects are not symmetric. In fact, these are much larger for positive rate surprises that inflict losses on mutual fund investors. In Panel D, we report results for the same regression as Panel B, but we only include Fed rate changes that induce positive surprises. The effect doubles in size: Fifty (20) days after the target rate change, a typical bond investor has lost 28.33 bps (22.26 bps.) per one bps. surprise. The 20-day return impact is almost twice as large as the one inferred from the Treasury yield estimates (5 times 2.31). Positive surprises also explain a surprisingly large share of the variation. At the 10-day horizon, the R^2 is 0.43.

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: IRF of U.S. Mutual Fund Returns

Panel A: No Target Changes					
Short Government Bonds					
1	**5**	**10**	**20**	**50**	**100**
-0.52	-1.96	0.59	-0.98	0.39	-6.35
[0.70]	[1.82]	[2.50]	[2.98]	[4.94]	[8.44]
(0.74)	(2.17)	(3.17)	(3.10)	(4.15)	(6.89)
0.01	0.03	0.00	0.00	0.00	0.01
Intermediate/Short Government Bonds					
1	**5**	**10**	**20**	**50**	**100**
-1.15	-4.44	-2.29	-5.54	-5.39	-6.16
[1.22]	[2.94]	[4.30]	[6.11]	[8.63]	[12.86]
(1.50)	(4.53)	(6.62)	(8.91)	(8.82)	(10.97)
0.02	0.06	0.01	0.02	0.01	0.01
Intermediate Government Bonds					
1	**5**	**10**	**20**	**50**	**100**
0.23	-5.92	-0.81	-4.51	4.21	-14.02
[1.50]	[4.18]	[5.68]	[8.18]	[11.16]	[18.40]
(1.45)	(5.64)	(7.57)	(8.84)	(8.68)	(17.32)
0.00	0.05	0.00	0.01	0.00	0.02
TIPS					
1	**5**	**10**	**20**	**50**	**100**
-2.48	-7.91	-6.63	-18.13	-23.19	1.13
[2.30]	[5.37]	[7.94]	[13.17]	[20.70]	[23.42]
(2.74)	(7.55)	(12.85)	(22.59)	(33.35)	(23.32)
0.03	0.05	0.02	0.05	0.03	0.00

Panel B: Target Changes					
Short Government Bonds					
1	**5**	**10**	**20**	**50**	**100**
-0.79	-1.28	-1.19	-1.36	-3.72	-3.30
[0.31]	[0.51]	[0.72]	[0.97]	[1.61]	[2.43]
(0.24)	(0.57)	(0.90)	(1.02)	(1.89)	(2.20)
0.13	0.13	0.06	0.05	0.11	0.04
Intermediate Short Government Bonds					
1	**5**	**10**	**20**	**50**	**100**
-1.30	-2.99	-3.01	-3.15	-9.08	-9.22
[0.45]	[0.72]	[1.11]	[1.73]	[2.65]	[3.50]
(0.37)	(0.94)	(1.42)	(1.81)	(3.40)	(3.42)
0.17	0.30	0.15	0.08	0.22	0.14
Intermediate Government Bonds					
1	**5**	**10**	**20**	**50**	**100**
-1.15	-3.64	-3.70	-6.36	-11.80	-9.28
[0.59]	[0.98]	[1.49]	[2.54]	[3.78]	[4.59]
(0.59)	(1.02)	(1.57)	(3.12)	(4.78)	(3.94)
0.08	0.25	0.13	0.13	0.19	0.09
TIPS					
1	**5**	**10**	**20**	**50**	**100**
-1.68	-5.84	-5.12	-3.93	-13.99	-15.10
[0.74]	[1.63]	[1.82]	[2.81]	[3.59]	[4.63]
(0.61)	(2.12)	(1.97)	(3.27)	(4.18)	(5.14)
0.11	0.24	0.16	0.05	0.27	0.21

IRF of U.S. mutual fund cumulative log returns to 100 basis points (Kuttner) surprise in FFR 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 FF 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.

$$r^k_{\tau_i+1\to\tau_i+j-1} = a_{k,j} + b_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots. \tag{7}$$

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.[5] The 50-day window here yields most return predictability. 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.

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 FFR: $r^k_{\tau_i+1\to\tau_i+j-1} = a_{k,j} + b_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots$. 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 FF 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 A10 of the Appendix.

[5]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).

5.3 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.[6] 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 8 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.

[6] 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.

After 6 months, the total outflow as % of TNA in response to 1 std surprise (10 bps) is 3.2% of the Total Net Assets of all gov bond MFs. If we apply this number to the total holdings of Treasurys by all mutual funds and money market funds, that is a $ 63 bn supply shock over a period of 6 months. In addition, corporate bond funds experience outflows of up to 1.5% of Total Net Assets ($ 2.2 trillion in 2017.Q2), while mortgage funds experience outflows of up to 6.2% of their Total Net Assets. (Source: ICI, Table 4: Total Net Assets by Investment Objective.)

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: IRF 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

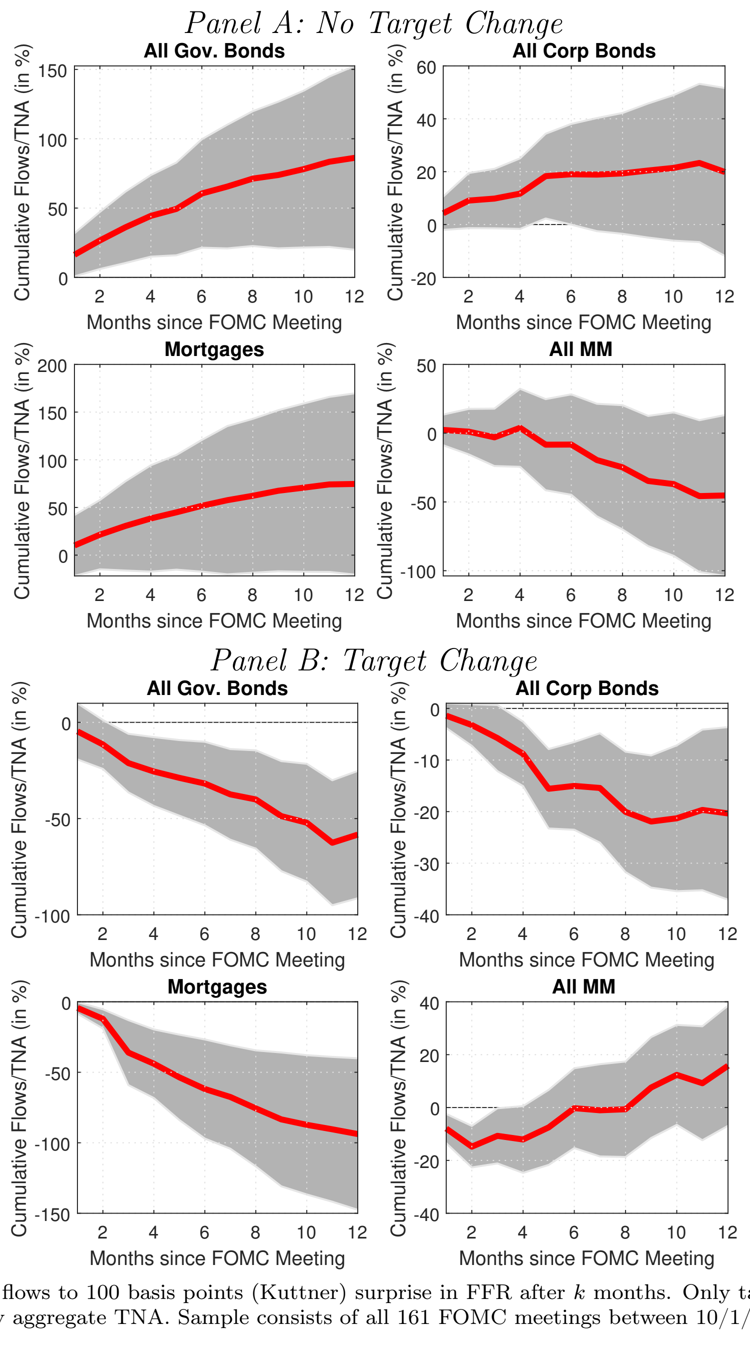
Panel B: Target Changes

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

IRF of cumulative U.S. mutual fund flows to 100 basis points (Kuttner) surprise in FFR 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 FF 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 FF 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 A11 in the separate appendix shows that these results continue

Figure 8: IRF of U.S. Mutual Fund Flows: Target Changes



IRF of U.S. mutual fund flows to 100 basis points (Kuttner) surprise in FFR 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.

to hold when we control for news about the path of future interest rates using Eurodollar deposit futures.

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

Panel A: No Target Changes

Short Government Bonds

1	**2**	**3**	**4**	**5**	**6**
0.23	0.33	0.47	0.59	0.68	0.84
[0.13]	[0.16]	[0.20]	[0.22]	[0.24]	[0.28]
(0.06)	(0.09)	(0.12)	(0.16)	(0.19)	(0.24)
0.03	0.04	0.06	0.07	0.08	0.09

Short/Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
0.19	0.36	0.55	0.69	0.78	0.93
[0.07]	[0.14]	[0.20]	[0.27]	[0.32]	[0.38]
(0.06)	(0.13)	(0.22)	(0.30)	(0.37)	(0.45)
0.08	0.07	0.08	0.07	0.06	0.07

Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
0.08	0.19	0.23	0.29	0.26	0.33
[0.04]	[0.06]	[0.08]	[0.10]	[0.14]	[0.17]
(0.03)	(0.06)	(0.09)	(0.12)	(0.17)	(0.19)
0.05	0.10	0.08	0.08	0.04	0.04

TIPS

1	**2**	**3**	**4**	**5**	**6**
0.22	0.41	0.49	0.62	0.76	0.82
[0.06]	[0.12]	[0.17]	[0.22]	[0.27]	[0.31]
(0.05)	(0.10)	(0.14)	(0.19)	(0.26)	(0.32)
0.13	0.13	0.09	0.09	0.09	0.08

Panel B: Target Changes

Short Government Bonds

1	**2**	**3**	**4**	**5**	**6**
-0.08	-0.18	-0.29	-0.40	-0.41	-0.46
[0.13]	[0.10]	[0.12]	[0.13]	[0.15]	[0.17]
(0.05)	(0.07)	(0.10)	(0.12)	(0.13)	(0.16)
0.01	0.06	0.09	0.13	0.12	0.12

Short/Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
-0.11	-0.24	-0.34	-0.44	-0.54	-0.61
[0.04]	[0.07]	[0.10]	[0.12]	[0.14]	[0.16]
(0.03)	(0.06)	(0.09)	(0.11)	(0.13)	(0.15)
0.13	0.19	0.19	0.20	0.22	0.22

Intermediate Government Bonds

1	**2**	**3**	**4**	**5**	**6**
-0.01	-0.02	-0.10	-0.08	-0.15	-0.15
[0.02]	[0.05]	[0.06]	[0.08]	[0.09]	[0.09]
(0.02)	(0.06)	(0.07)	(0.13)	(0.14)	(0.14)
0.00	0.00	0.05	0.02	0.05	0.04

TIPS

1	**2**	**3**	**4**	**5**	**6**
0.01	-0.11	-0.22	-0.21	-0.23	-0.27
[0.05]	[0.09]	[0.11]	[0.14]	[0.17]	[0.19]
(0.05)	(0.09)	(0.11)	(0.14)	(0.15)	(0.17)
0.00	0.03	0.06	0.04	0.03	0.04

IRF of cumulative U.S. mutual fund flows to 100 basis points (Kuttner) surprise in FFR 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 FF Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008.

Finally, Table A13 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.

5.4 Mutual Fund Returns and Mutual Fund 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. This implies a demand elasticity of 2.7 (i.e. the % change in demand relative to % change in price). This estimate is at the low end of the range of demand elasticity estimates for individual stocks (see Wurgler and Zhuravskaya, 2002, for an overview). 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						**Panel B: IV in all Months**					
	All Government Bonds						*All Government Bonds*					
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
	-2.02	0.22	2.26	2.22	2.17	1.30	6.21	5.44	4.91	4.96	5.19	5.38
	[1.76]	[1.77]	[0.96]	[0.64]	[0.58]	[0.39]	[3.08]	[2.42]	[2.04]	[1.85]	[1.74]	[1.65]
	(1.50)	(1.81)	(0.63)	(0.70)	(0.69)	(0.40)	(2.85)	(2.09)	(1.81)	(1.58)	(1.38)	(1.26)
	0.01	0.00	0.03	0.07	0.08	0.07	0.02	0.02	0.02	0.03	0.03	0.04
	Short Government Bonds						*Short Government Bonds*					
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
	-1.31	-0.26	0.78	2.27	4.20	4.09	2.09	2.07	2.05	2.16	2.30	2.43
	[0.58]	[0.66]	[0.56]	[0.56]	[0.65]	[0.61]	[1.42]	[1.16]	[1.02]	[0.95]	[0.91]	[0.88]
	(0.55)	(0.64)	(0.46)	(0.85)	(0.53)	(0.47)	(1.34)	(1.03)	(0.90)	(0.81)	(0.74)	(0.70)
	0.03	0.00	0.01	0.10	0.21	0.22	0.01	0.01	0.02	0.02	0.02	0.03
	Short/Intermediate Government Bonds						*Short/Intermediate Government Bonds*					
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
	6.79	6.08	5.53	4.57	4.93	4.44	3.17	2.85	2.71	2.77	2.91	3.00
	[1.78]	[1.38]	[1.18]	[1.00]	[0.92]	[0.84]	[1.29]	[1.07]	[0.94]	[0.87]	[0.82]	[0.79]
	(1.63)	(1.37)	(1.06)	(0.94)	(0.89)	(0.80)	(1.17)	(0.94)	(0.84)	(0.75)	(0.67)	(0.62)
	0.09	0.12	0.13	0.13	0.17	0.16	0.02	0.03	0.03	0.04	0.05	0.05
	Intermediate Government Bonds						*Intermediate Government Bonds*					
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
	3.09	11.52	0.92	0.85	0.72	0.45	9.91	9.10	7.75	7.79	8.09	8.43
	[5.50]	[4.00]	[0.45]	[0.31]	[0.29]	[0.18]	[4.95]	[4.19]	[3.68]	[3.42]	[3.27]	[3.17]
	(6.86)	(5.42)	(0.19)	(0.14)	(0.14)	(0.11)	(4.57)	(3.81)	(3.48)	(3.22)	(2.96)	(2.71)
	0.00	0.05	0.03	0.05	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.03
	TIPS						*TIPS*					
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
	10.71	10.18	11.11	8.99	8.76	8.03	14.79	13.10	10.77	10.05	12.43	14.99
	[3.72]	[3.07]	[2.49]	[2.02]	[1.76]	[1.68]	[11.32]	[9.87]	[8.97]	[8.53]	[8.42]	[8.39]
	(4.88)	(2.65)	(2.08)	(1.92)	(1.57)	(1.32)	(12.05)	(10.37)	(9.29)	(8.76)	(8.74)	(8.11)
	0.06	0.07	0.12	0.12	0.15	0.14	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 FF 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. FF target rate changes trigger large, gradual flows out of or into fixed income funds that cannot be readily absorbed by other market participants.

5.5 Other Investors

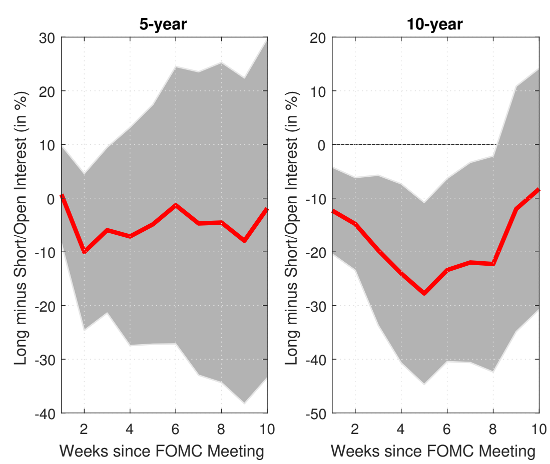
There is a growing body of evidence that arbitrage capital moves slowly, even in response to anticipated events, even in developed, liquid asset markets: index reconstitutions in the stock market (Shleifer, 1986; Greenwood, 2008) and Treasury auctions (Lou, Yan, and Zhang, 2013) are two prominent examples 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.

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

$$(NonCommercial\ Long\ minus\ NonCommercial\ Short)/NonCommercial\ Open\ Interest$$

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 9: IRF of Speculative Interest



IRF of U.S. Treasurys in bps with Constant Maturity to 1 bps (Kuttner) surprise in FFR after k days. Full sample contains 59 FF Target Changes on regularly scheduled FOMC meetings between 5-June-1989 and 29-Oct-2008.

This section also provides some tentative evidence on the response of foreign investors, other intermediaries and institutional investors. First, we use the monthly TIC data from the U.S. Treasury to examine net purchases by foreign investors in the wake of rate surprises. These results are reported in Table A8 of the separate Appendix. After a rate change, foreign investors act as liquidity providers by purchasing Treasurys in response to a surprise rate increase. In response to a 10 bps. surprise, foreign investors would on average purchase Treasurys and Agencys equivalent to 2.7% of foreign Treasury holdings.

Second, we use the quarterly Federal Flow of Funds data to examine Treasury purchases and sales by other U.S. Investors. This data does not distinguish between T-Bills and other Treasurys. Given the quarterly frequency and the nature of the data, these estimated impulse responses are less precise. The results are reported in Table A9 of the Separate Appendix. In 2018 Q.2, banks held 4.29% of the marketable supply of Treasurys. Insurance companies held 2.41%, while pension funds held 17.04%. Money market funds hold 4.88%, while mutual funds hold about 8.35%. Finally, GSEs hold 0.78%, broker-dealers hold .79%, and the rest of the world holds about 42%. Holdings by banks, pension funds and insurance companies are quite stable, but mutual fund holdings and broker-dealer holdings are quite volatile.

Consistent with our other results, mutual funds sell up to 0.179% of the total supply of marketable Treasuries (or 5.4 % of their Treasury holdings) after 4 quarters in response to a 10 bps rate increase. Interestingly, GSE's and banks sell another 0.52% after 4 quarters. These highly levered financial institutions suffer losses in response to a rate hike because of the duration mismatch on their balance sheet, and as a result, they may see fit to further reduce holdings of long-dated assets as their Treasury holdings are marked down, because of price pressure from mutual fund flows. Alternatively, some of these banks may decide to front-run mutual fund and other slower investors. By contrast, the largest U.S. holder of Treasurys, pension funds, do not significantly adjust their holdings in response to these shocks.

6 Sticky Expectations Hypothesis

There is a growing body of evidence that some of the statistical evidence in favor of bond return predictability is driven by investors' expectational errors about future rates rather than bond risk premia (see Piazzesi and Schneider, 2011; Cieslak, 2018). We develop a model in which mutual fund investors are slow to update expectations about future short rates. In addition, these investors extrapolate when forecasting future short rates.

We consider a model in which mutual fund bond investors do not have rational short rate expectations. We use a simple version of the Mankiw and Reis (2002) model of sticky information to analyze the impact on bond prices. After an FOMC target change, in any given period, only a fraction $(1-\lambda)$ of mutual fund investors update their information set. This model is similar to the one used by Katz, Lustig, and Nielsen (2017) to analyze the response of stock prices to inflation news. Consistent with this hypothesis, Coibion and Gorodnichenko (2015) document evidence of information stickiness in inflation expectation surveys that is economically significant. Rational inattention could potentially rationalize stickiness.

There is a continuum of mutual fund investors. Each invests in a different bond fund. When we aggregate across all mutual fund investors, we then end up with discount rates that are sticky. Obviously, this creates profit opportunities for sophisticated investors who are not subject to sticky short-rate expectations, but instead use superior and continuously updated short-rate forecasts.

Instead of pricing the bond funds, we will price the zero coupon bonds directly. Equation (1) has to hold for every sample path. That means it also holds for every individual investor's expectation for his individual bond portfolio

$$y_t^{i,N,mf} = \mathbb{E}_{t-l(i)}^i \frac{1}{N} \left[\sum_{j=1}^{N} r_{t+j-1}^{\$} \right], \tag{8}$$

where $t-l(i)$ denotes the last period when i updated her discount rate forecasts. When they update their information set, investors use the following stochastic process for the short rate, specified as: $r_{t+1}^{\$} = (1-\phi_{mf})\theta + \phi_{mf} r_t^{\$} + u_{t+1}$, where $0 < \phi^{mf} < 1$ denotes the AR(1) coefficient, while θ is the investor's estimate of the unconditional mean of the nominal short rate. We allow for the possibility that mutual fund investors extrapolate when forecasting short rates: $\phi_{mf} > \phi$. This extrapolative behavior is what Cieslak (2018) documents in survey forecasts of FFR compared to statistical forecasts; the survey respondents put more weights on the current short rate and less weights on other information (e.g., the employment report). The dynamics of survey forecasts of FFR are consistent with investors extrapolating the current FFR and ignoring other information.

Next, we aggregate across individual mutual fund investors to end up with the following expression for the average log bond yield that is desired by mutual fund investors:

$$y_t^{N,mf} = \mathbb{F}_t \frac{1}{N} \left[\sum_{j=1}^{N} r_{t+j-1}^{\$} \right], \tag{9}$$

where $\mathbb{F}_t$ denotes the cross-sectional average of the sticky information forecasts. Reis (2006) shows that the cross-sectional average forecast of a variable x_t h periods from now is simply given by: $\mathbb{F}^i_t x_{t+h} = (1-\lambda)\sum_{j=0}^{\infty} \lambda_i^j \mathbb{E}_{t-j} x_{t+h}$. We can substitute the AR(1)-forecast of inflation into this expression to obtain the cross-sectional average short-rate forecast: $\mathbb{F}_t r^{\$}_{t+h} = (1-\lambda)\sum_{j=0}^{\infty} \lambda^j \phi_{mf}^{j+h}(r^{\$}_{t-j} - \theta) + \theta$. The h-period rate forecast is an infinite moving average of past rates. Plugging these expressions into the expression in Equation (9) yields the following result for the average log yield perceived by mutual fund investors.

Proposition 1. *The average 'target' nominal yield desired by mutual fund investors with sticky expectations is given by:*

$$y_t^{N,mf} - \theta = \frac{1}{N}\sum_{j=0}^{\infty} \frac{(\lambda)^j (1-\lambda)\left(1-\phi_{mf}^N\right)}{1-\phi_{mf}} \phi_{mf}^j (r^{\$}_{t-j} - \theta).$$

The average nominal yield that is desired by mutual fund investors is an infinite moving average of past short rates. The moving average weights are governed by the relative degree of information stickiness in short rate expectations. As expected, an increase in the current short rate above the unconditional mean immediately increases the target nominal yield, but not by enough. A fraction λ of agents fail to update short rate expectations. As a result, the target nominal yield is too low. However, as more agents update in subsequent periods, yields continue to increase, which explains the positive effect of lagged short rates on the nominal yield perceived today.

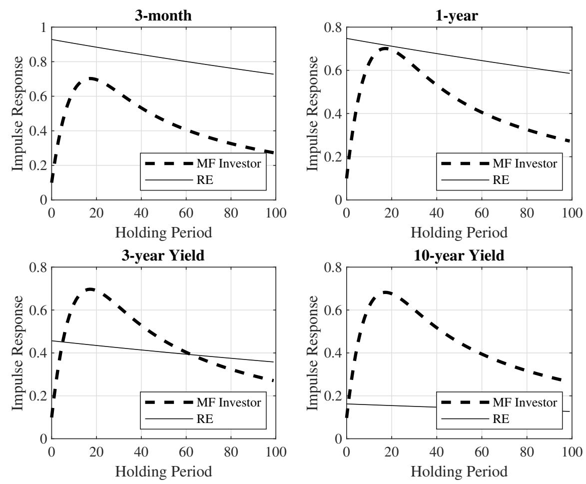
Proposition 2. *The impulse response of the average 'target' yield to a short rate shock k periods ago is given by:*

$$\frac{\Delta y_{t+k}^{N,mf}}{\Delta r_t^{\$}} = \phi^k \frac{1}{N} \frac{(1-\lambda)\left(1-\phi_{mf}^N\right)\left(1-(\lambda(\frac{\phi_{mf}}{\phi}))^{k+1}\right)}{(1-\phi_{mf})(1-\lambda(\frac{\phi_{mf}}{\phi}))}.$$

The larger λ, the slower the adjustment to the shock.

We start by assuming that the marginal investor has rational expectations, and bond prices follow the benchmark model's response. The full line in Figure 10 plots the the rational expectations response to a 100 bps short rate shock when the monthly persistence of the short rate ϕ is 0.95.

Figure 10: IRF of Yields–Sticky Expectations



Response in bps. of yields in Rational Expectations Hypothesis Model (full line) and Sticky Information Model (dotted line) to a 1 bps shock. The monthly persistence of the short rate $\phi =$ is set to 0.9 and the perceived persistence ϕ_{mf} is set to 0.995. λ is equal to 0.90 (daily frequencies).

The response of the target nominal bond yield desired by mutual fund investors with sticky expectations exceeds the Rational Expectations response if

$$\frac{(1-\lambda)\left(1-\phi_{mf}^{N}\right)\left(1-(\lambda(\frac{\phi_{mf}}{\phi}))^{k+1}\right)}{(1-\phi_{mf})(1-\lambda(\frac{\phi_{mf}}{\phi}))} > \frac{\left(1-\phi^{N}\right)}{(1-\phi)}.$$

This overshooting condition can only be satisfied if mutual fund investors extrapolate: $\phi_{mf} > \phi$, because when $\phi_{mf} = \phi$, this inequality cannot be satisfied. When this overshooting condition is satisfied, the average mutual fund investor considers the nominal bond yield too low (or, equivalently), the price is too high (low), after an increase (decrease) in the short rate. The average mutual fund investor will sell (buy) after an increase (decrease) in the short rate.

The dashed line in Figure 10 plots the response of the average yield desired by mutual fund investors when the perceived persistence is much higher than the actual one: $\phi_{mf} = 0.995$. When the mutual fund investor's yield target crosses the RE response, the average mutual fund investor starts selling her holdings, after an increase in the short rate. This crossing happens sooner for longer maturity bonds, because extrapolative investors who update reprice longer maturity bonds more aggressively. The price pressure that results can push yields up even further, especially for longer maturity bonds.

If the actual yield on each individual bond fund equals the target yield, then this mutual fund investor who has just updated expectations will not sell her holdings. That being the case, the actual aggregate bond yield in each period equals this target yield perceived by mutual fund investors $y_t^{N,mf}$. Given these actual yields, none of the mutual fund investors will sell in response to a short rate increase (decrease). In this extreme case, we can derive a simple expression for the log bond returns. Then the nominal log return is given by the following expression:

$$\begin{aligned} r_{t+1}^N &= \sum_{j=0}^{\infty} \frac{(\lambda)^j (1-\lambda)\left(1-\phi_{mf}^N\right)}{1-\phi_{mf}} \phi_{mf}^j (r_{t-j}^{\$} - \theta) \\ &- \sum_{j=0}^{\infty} \frac{(\lambda)^j (1-\lambda)\left(1-\phi_{mf}^{N-1}\right)}{1-\phi_{mf}} \phi_{mf}^j (r_{t+1-j}^{\$} - \theta). \end{aligned}$$

It is informative to explore the size of profit opportunities in the extreme case in which the mutual fund investors are pricing bonds.

Proposition 3. *The excess return expected by a rational investor and the corresponding Sharpe ratio, both conditional on information at t, are given by:*

$$\begin{aligned} \mathbb{E}_t[r_{t+1}^N - r_t^{\$}] &= \frac{(1-\lambda)\left((1-\phi_{mf}^N) - (\phi_{mf}\lambda + \phi)(1-\phi_{mf}^{N-1})\right) - (1-\phi_{mf})}{1-\phi_{mf}} (r_t^{\$} - \theta). \\ SR_t\left[r_{t+1}\right] &= \frac{(1-\lambda)\left((1-\phi_{mf}^N) - (\phi_{mf}\lambda + \phi)(1-\phi_{mf}^{N-1})\right) - (1-\phi_{mf})}{(1-\lambda)\left(1-\phi_{mf}^{N-1}\right)\sigma_r} (r_t^{\$} - \theta). \end{aligned}$$

A rational investor, when confronted with these sticky yields, would choose to short the bonds in case of a rate increase, as can easily be verified from the first expression for the expected excess return. As the fraction of agents updating converges to one $(1-\lambda) \to 1$, the expected excess return converges to zero, provided that mutual funds investors use the right DGP when they update: $\phi = \phi_{mf}$. The Sharpe ratio depends on the fundamental volatility of the short rate process.

7 Dynamic IRF of Treasury Yields: Robustness

There are three concerns that we address in this section. First, our estimated IRF 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 FFR. Second, the regression windows overlap. Given that the FFR 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.

7.1 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 FFR 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 FFR revealed on the same day:

$$y^k_{\tau_i+j-1} - y_{\tau_i-1} = a_{k,j} + \beta_{k,j}\left(-\Delta r^u_{\tau_i}\right) + \gamma_{4,j}(f^4_{\tau_i} - f^4_{\tau_i-1}) + \gamma_{8,j}(f^8_{\tau_i} - f^8_{\tau_i-1}) + \varepsilon^{k,j}_{\tau_i+j}, j = 1, 2, \ldots. \tag{10}$$

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 FF 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 FFR is 25 basis lower than investors expected. However, the Fed could signal that it would increase the FFR 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: IRF of U.S. Treasurys 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

IRF of U.S. Treasurys in bps with Constant Maturity to 1 bps (Kuttner) surprise in FFR 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 $k \geq 75$.

7.2 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	58.00	57.00	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 A14 in the appendix reports the results for $k = 50, 100$. In Panel A of Table A14, 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 A15 in the Appendix reports the results for $k = 50, 100$. The results are in line with the other results.

Finally, Table A16 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 A17 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.

7.3 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 A18 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 FF 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 FF 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 (2018a). 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 FF 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 A19 in the appendix considers target changes separately. As before, the evidence for sluggish adjustment is much stronger following target changes. Finally, Table A20 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: IRF of U.S. Treasurys 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

IRF of U.S. Treasurys in bps with Constant Maturity to 1 bps (Kuttner) surprise in FFR 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 $k \geq 75$.

8 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. FF 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.

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A Proofs

Proof of Proposition 1:

Proof. Note that: $\mathbb{F}_t r^{\$}_{t+h} = (1-\lambda)\sum_{j=0}^{\infty}\lambda^j\phi^{j+h}(r^{\$}_{t-j}-\theta)+\theta$. In the case of information stickiness, the discount rate component is given by:

$$\mathbb{F}_t\left[\sum_{k=1}^{N} r^{\$}_{t+k-1}\right] = \mathbb{F}_t\left[\sum_{k=0}^{N-1} r^{\$}_{t+k}\right] = \sum_{k=0}^{\infty}(1-\lambda)\sum_{j=0}^{\infty}(\lambda)^j\phi_{mf}^{j+k}(r^{\$}_{t-j}-\theta),$$

which can be simplified as

$$\begin{aligned}\mathbb{F}_t^r\left[\sum_{k=1}^{\infty} r^{\$}_{t+k}\right] &= \sum_{j=0}^{\infty}(\lambda)^j(1-\lambda)(r^{\$}_{t-j}-\theta)\sum_{k=0}^{N-1}\phi_{mf}^{j+k}, \\ &= \sum_{j=0}^{\infty}(\lambda)^j(1-\lambda)\frac{\phi_{mf}^j(1-\phi_{mf}^N)}{1-\phi_{mf}}(r^{\$}_{t-j}-\theta).\end{aligned}$$

We end up with the following expression for the log nominal yield desired by the average investor:

$$y_t^N - \theta = \sum_{j=0}^{\infty}\frac{(\lambda)^j(1-\lambda)\left(1-(\phi_{mf})^N\right)}{1-\phi_{mf}}\phi^j(r^{\$}_{t-j}-\theta).$$

□

Proof of Proposition 2:

Proof. The impulse response of the average yields to a short rate shock k periods ago:

$$\frac{\Delta y^{N,mf}_{t+k}}{\Delta r^{\$}_t} = \frac{1}{N}\sum_{j=0}^{k}\frac{(\lambda)^j(1-\lambda)\left(1-\phi_{mf}^N\right)}{1-\phi_{mf}}\phi_{mf}^j\phi^{k-j}.$$

This follows directly for the expression for the average yield

$$y^{N,mf}_{t+k} - \theta = \frac{1}{N}\sum_{j=0}^{\infty}\frac{(\lambda)^j(1-\lambda)\left(1-\phi_{mf}^N\right)}{1-\phi_{mf}}\phi_{mf}^j(r^{\$}_{t+k-j}-\theta).$$

Note that $\mathbb{E}_t(r^{\$}_{t+k-j}-\theta) = \phi^{k-j}E_t(r^{\$}_t-\theta)$. This impulse response can then be restated as follows:

$$\frac{\Delta y_{t+k}^{N,mf}}{\Delta r_t^{\$}} = \phi^k \frac{1}{N} \sum_{j=0}^{k} \frac{(\lambda)^j (1-\lambda)\left(1-\phi_{mf}^N\right)}{1-\phi_{mf}} (\frac{\phi_{mf}}{\phi})^j \tag{11}$$

$$= \phi^k \frac{1}{N} \frac{(1-\lambda)\left(1-\phi_{mf}^N\right)\left(1-(\lambda(\frac{\phi_{mf}}{\phi}))^{k+1}\right)}{(1-\phi_{mf})(1-\lambda(\frac{\phi_{mf}}{\phi}))}.$$

□

Proof of Proposition Proposition 3:

Proof. Next, we derive an expression for nominal returns on the bond market. We use L to denote the lag operator. The nominal log return can be expressed as:

$$r_{t+1}^N = \sum_{j=0}^{\infty} \frac{(\lambda)^j (1-\lambda)\left(1-\phi_{mf}^N\right)}{1-\phi_{mf}} \phi_{mf}^j (r_{t-j}^{\$} - \theta) - \sum_{j=0}^{\infty} \frac{(\lambda)^j (1-\lambda)\left(1-\phi_{mf}^{N-1}\right)}{1-\phi_{mf}} \phi_{mf}^j (r_{t+1-j}^{\$} - \theta).$$

The (rational investor's) expected return conditional on information at t by a rational investor is given by:

$$\mathbb{E}_t r_{t+1} = \frac{(1-\lambda)\left(1-\phi_{mf}^N\right)}{1-\phi_{mf}} (r_t^{\$} - \theta) - \frac{(\lambda)(1-\lambda)\left(1-\phi_{mf}^{N-1}\right)}{1-\phi_{mf}} \phi_{mf} (r_t^{\$} - \theta) - \frac{(1-\lambda)\left(1-\phi_{mf}^{N-1}\right)}{1-\phi_{mf}} \phi (r_t^{\$} - \theta).$$

This can be simplied as follows:

$$\mathbb{E}_t r_{t+1} = \frac{(1-\lambda)}{1-\phi_{mf}} \left((1-\phi_{mf}^N) - (\phi_{mf}\lambda + \phi)(1-\phi_{mf}^{N-1})\right).$$

As a result, the excess return expected by a rational investor and the corresponding Sharpe ratio, both conditional on information at t, are given by:

$$\mathbb{E}_t[r_{t+1}^N - r_t^{\$}] = \frac{(1-\lambda)\left((1-\phi_{mf}^N) - (\phi_{mf}\lambda + \phi)(1-\phi_{mf}^{N-1})\right) - (1-\phi_{mf})}{1-\phi_{mf}} (r_t^{\$} - \theta).$$

$$SR_t\left[r_{t+1}\right] = \frac{(1-\lambda)\left((1-\phi_{mf}^N) - (\phi_{mf}\lambda + \phi)(1-\phi_{mf}^{N-1})\right) - (1-\phi_{mf})}{(1-\lambda)\left(1-\phi_{mf}^{N-1}\right)\sigma_r} (r_t^{\$} - \theta).$$

At longer horizons, the nominal log return can be expressed as follows:

$$
\begin{aligned}
r^N_{t+k} &= \sum_{j=0}^{\infty} \frac{(\lambda)^j (1-\lambda)\left(1-\phi^N_{mf}\right)}{1-\phi_{mf}} \phi^j_{mf} (r^\$_{t-j} - \theta) \\
&- \sum_{j=0}^{\infty} \frac{(\lambda)^j (1-\lambda)\left(1-\phi^{N-1}_{mf}\right)}{1-\phi_{mf}} \phi^j_{mf} (r^\$_{t+k-j} - \theta).
\end{aligned}
$$

The (rational investor's) expected return conditional on information at t by a rational investor is given by:

$$
\begin{aligned}
\mathbb{E}_t r_{t+k} &= \frac{(1-\lambda)\left(1-\phi^N_{mf}\right)}{1-\phi_{mf}} (r^\$_t - \theta) \\
&- \sum_{j=0}^{k} \frac{(\lambda)^j (1-\lambda)\left(1-\phi^{N-1}_{mf}\right)}{1-\phi_{mf}} \phi^j_{mf} \phi^{k-j} (r^\$_t - \theta).
\end{aligned}
$$

$$
\begin{aligned}
\mathbb{E}_t r_{t+k} &= \frac{(1-\lambda)\left(1-\phi^N_{mf}\right)}{1-\phi_{mf}} (r^\$_t - \theta) \\
&- \phi^k \frac{(1-\lambda)\left(1-\phi^N_{mf}\right)\left(1-(\lambda(\frac{\phi_{mf}}{\phi}))^{k+1}\right)}{(1-\phi_{mf})(1-\lambda(\frac{\phi_{mf}}{\phi}))}.
\end{aligned}
$$

□