The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases*

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Since December 2008, the Federal Reserve's traditional policy instrument, the target federal funds rate, has been effectively at its lower bound of zero. In order to further ease the stance of monetary policy as the economic outlook deteriorated, the Federal Reserve purchased substantial quantities of assets with medium and long maturities. In this paper, we explain how these purchases were implemented and discuss the mechanisms through which they can affect the economy. We present evidence that the purchases led to economically meaningful and long-lasting reductions in longer-term interest rates on a range of securities, including securities that were not included in the purchase programs. These reductions in interest rates primarily reflect lower risk premiums, including term premiums, rather than lower expectations of future short-term interest rates.

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1.   Introduction

In December 2008, the Federal Open Market Committee (FOMC) lowered the target for the federal funds rate to a range of 0 to 25 basis points. With its traditional policy instrument set as low as possible, the Federal Reserve faced the challenge of how to further ease the stance of monetary policy as the economic outlook deteriorated. The Federal Reserve responded in part by purchasing substantial quantities of assets with medium and long maturities in an effort to drive down private borrowing rates, particularly at longer maturities. These large-scale asset purchases (LSAPs) have greatly increased the size of the Federal Reserve's balance sheet, and the additional assets may remain in place for years to come.

To be sure, the Federal Reserve undertook other important initiatives to combat the financial crisis. It launched a number of facilities to relieve financial strains at specific types of institutions and in specific markets. In addition, in an attempt to provide even more stimulus, it used public communications about its policy intentions to lower market expectations of the federal funds rate in the future. All of these strategies were designed to ease financial conditions and to support a sustained economic recovery. Over time, though, the credit extended by the liquidity facilities has declined and the dominant component of the Federal Reserve's balance sheet has become the assets accumulated under the LSAP programs.

The decision to purchase large volumes of assets came in two steps. In November 2008, the Federal Reserve announced purchases of housing agency debt and agency mortgage-backed securities (MBS) of up to $600 billion. In March 2009, the FOMC decided to substantially expand its purchases of agency-related securities and to purchase longer-term Treasury securities as well, with total asset purchases of up to $1.75 trillion, an amount twice the magnitude of total Federal Reserve assets prior to 2008.[1] The FOMC stated that

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[1]The Treasury Department also established a program to purchase agency MBS beginning in September 2008. By its termination at year-end 2009, it had purchased $220 billion of such securities. This program was much smaller than the Federal Reserve LSAPs and no specific purchase amount targets were announced, so it is not included in our analysis.

the increased purchases of agency-related securities should "provide greater support to mortgage lending and housing markets" and that purchases of longer-term Treasury securities should "help improve conditions in private credit markets."

In this paper, we review the Federal Reserve's experience with implementing the LSAPs and describe some of the challenges raised by such large purchases in a relatively short time. In addition, we discuss the economic mechanisms through which LSAPs may be expected to stimulate the economy and present some empirical evidence on those effects. In particular, LSAPs reduce the supply to the private sector of assets with long duration (and, in the case of mortgage securities, highly negative convexity) and increase the supply of assets (bank reserves) with zero duration and convexity.[2] To the extent that private investors do not view these assets as perfect substitutes, the reduction in supply of the riskier longer-term assets reduces the risk premiums required to hold them and thus reduces their yields. We assess the extent to which LSAPs had the desired effects on market interest rates using two different approaches and find that LSAPs caused economically meaningful and long-lasting reductions in longer-term interest rates on a range of securities, including securities that were not included in the purchase programs. We show that these reductions in interest rates primarily reflect lower risk premiums rather than lower expectations of future short-term interest rates.[3] We briefly examine the experiences of Japan and the United Kingdom with LSAPs and find effects that are generally consistent with those found in the United States. We conclude with a discussion of issues raised by these policies and potential lessons for implementing monetary policy at the zero bound in the future.

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[2]Negative convexity arises from the ability of mortgage borrowers to prepay their loans. As interest rates fall, the incentive to prepay increases, generally resulting in an increase in prepayments to MBS holders. This effect causes the duration of MBS to fall as interest rates decline and vice versa. Convexity is explained in more detail in the next section.

[3]As we discuss below, these risk premiums, or excess expected returns, arise due to interest rate, credit, or liquidity risk, or other characteristics that make the assets' returns uncertain.

2. How Large-Scale Asset Purchases (LSAPs) Affect the Economy

The primary channel through which LSAPs appear to work is by affecting the risk premium on the asset being purchased. By purchasing a particular asset, a central bank reduces the amount of the security that the private sector holds, displacing some investors and reducing the holdings of others, while simultaneously increasing the amount of short-term, risk-free bank reserves held by the private sector. In order for investors to be willing to make those adjustments, the expected return on the purchased security has to fall. Put differently, the purchases bid up the price of the asset and hence lower its yield. This pattern was described by Tobin (1958, 1969) and is commonly known as the "portfolio balance" effect.[4]

Note that the portfolio balance effect has nothing to do with the expected path of short-term interest rates. Longer-term yields can be parsed into two components: the average level of short-term risk-free interest rates expected over the term to maturity of the asset and the risk premium. The former represents the expected return that investors could earn by rolling over short-term risk-free investments, and the latter is the expected additional return that investors demand for holding the risk associated with the longer-term asset. In theory, the effects of the LSAPs on longer-term interest rates could arise by influencing either of these two components. However, the Federal Reserve did not use LSAPs as an explicit signal that the future path of short-term risk-free interest rates would remain low.[5] In fact, at the same time that the Federal Reserve was expanding its

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[4]There is a large body of literature on consumer optimizing models of portfolio selection, which are variants of the portfolio balance model that impose restrictions arising from the assumed (risk averse) utility functions of investors. See Markowitz (1952), Sharpe (1964), and Campbell and Viceira (2001, 2005). More recently, Vayanos and Vila (2009) have developed a theoretical model of the term structure based on preferred habitats of investors, which also relies on risk aversion. Andres, López-Salido, and Nelson (2004) provide an example of a dynamic stochastic general equilibrium model with imperfect asset substitutability based on frictions in financial markets.

[5]Indeed, the FOMC instead directly used language in its statements to signal that it anticipates that short-term interest rates will remain exceptionally low for an extended period. However, as discussed below, neither the language about future policy rates in the FOMC statements nor the LSAP announcements appear to have had a substantial effect on the expected future federal funds rate.

balance sheet through the LSAPs, it was going to great lengths to inform investors that it would still be able to raise short-term interest rates at the appropriate time. Thus, any reduction in longer-term yields instead has likely come through a narrowing in risk premiums.

For Treasury securities, the most important component of the risk premium is referred to as the "term premium," and it reflects the reluctance of investors to bear the interest rate risk associated with holding an asset that has a long duration. The term premium is the additional return investors require, over and above the average of expected future short-term interest rates, for accepting a fixed, long-term yield. The LSAPs have removed a considerable amount of assets with high duration from the markets. With less duration risk to hold in the aggregate, the market should require a lower premium to hold that risk. This effect may arise because those investors most willing to bear the risk are the ones left holding it.[6] Or, even if investors do not differ greatly in their attitudes toward duration risk, they may require lower compensation for holding duration risk when they have smaller amounts of it in their portfolios.

In addition to the effect of removing duration and hence shrinking the term premium across all asset classes, Federal Reserve purchases of agency debt and agency MBS might be expected to have an additional effect on the yields on those assets through other elements of their risk premiums. For example, these assets may be seen as having greater credit or liquidity risk than Treasury securities.[7] In addition, the purchases of MBS reduce the amount of prepayment risk that investors have to hold in the aggregate. Prepayment risk on MBS causes the duration of MBS to shrink when interest rates decline and rise when interest rates increase. These changes in duration imply that MBS have negative convexity: compared with the

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[6]Indeed, in the preferred-habitat model of Modigliani and Sutch (1966) it is possible that some agents seek to hold long-duration assets—e.g., for retirement—so that the term premium can, in principle, be negative.

[7]Prior to December 2009, the Treasury had committed to sizable but limited capital injections in the housing agencies, and thus had not issued a blanket guarantee of agency obligations. On December 24, 2009, the Treasury removed the limit on capital injections over the next three years, stating that it wished to "leave no uncertainty about the Treasury's commitment to support these firms." Agency debt and agency MBS are not as liquid as Treasury securities. The direct effect of LSAPs on liquidity of these securities is considered further below.

price of a non-callable bond with the same coupon and maturity, MBS prices rise less when rates fall and decline more when rates rise. Given this undesirable profile and the cost of hedging against it, investors typically demand an extra return to bear the negative convexity risk, keeping MBS rates higher than they would otherwise be. The LSAPs removed a considerable amount of assets with high convexity risk, which would be expected to reduce MBS yields.

These portfolio balance effects should not only reduce longer-term yields on the assets being purchased but should also spill over into the yields on other assets. The reason is that investors view different assets as substitutes and, in response to changes in the relative rates of return, will attempt to buy more of the assets with higher relative returns. In this case, lower prospective returns on agency debt, agency MBS, and Treasury securities should cause investors to seek to shift some of their portfolios into other assets such as corporate bonds and equities and thus should bid up their prices. It is through the broad array of all asset prices that the LSAPs would be expected to provide stimulus to economic activity. Many private borrowers would find their longer-term borrowing costs lower than they would otherwise be, and the value of long-term assets held by households and firms, and thus aggregate wealth, would be higher.

The effects described so far would be caused by LSAP-induced changes in the stock of assets that is held by the public. Moreover, to the extent that investors care about expected future returns on their assets, today's asset prices should reflect expectations about the future stock of assets. Thus, a credible announcement that the Federal Reserve will purchase longer-term assets at a future date should reduce longer-term interest rates immediately. Otherwise, investors could make excess profits by buying the assets today to sell to the Federal Reserve in the future.

There may also be effects on the prices of longer-term assets if the presence of the Federal Reserve as a consistent and significant buyer in the market enhances market functioning and liquidity. The LSAP programs began at a point of significant market strains, and the poor liquidity of some assets weighed on their prices. By providing an ongoing source of demand for longer-term assets, the LSAPs may have allowed dealers and other investors to take larger positions in these securities or to make markets in them more actively, knowing that they could sell the assets if needed to the Federal Reserve.

Such improved trading opportunities could reduce the liquidity risk premiums embedded in asset prices, thereby lowering their yields.[8]

This liquidity, or market functioning, channel, which is distinct from the portfolio balance channel, appears to have been important in the early stages of the LSAP programs for certain types of assets. For example, the LSAP programs began at a point when the spreads between yields on agency-related securities and yields on Treasury securities were well above historical norms, even after adjusting for the convexity risk in MBS associated with the high interest rate volatility at that time. These spreads in part reflected poor liquidity and elevated liquidity risk premiums on these securities.[9] The flow of Federal Reserve purchases may have helped to restore liquidity in these markets and reduced the liquidity risk of holding those securities, thereby narrowing the spreads of yields on agency debt and MBS to yields on Treasury securities and reducing the cost of financing agency-related securities.

Another asset for which the market functioning channel was important in the early stages of the LSAP programs is older Treasury securities, which had become unusually cheap relative to more recently issued Treasury securities with comparable maturities.[10] Such differences would normally be arbitraged away, but investors and dealers were reluctant to buy the older securities because their poor liquidity meant that they might be difficult to sell. However, after the Federal Reserve began buying such bonds, the yield spreads narrowed to normal levels.

Overall, LSAPs may affect market interest rates through a combination of portfolio balance and market functioning effects. Although the effects on market functioning appear to have been important at the start of the LSAPs when financial markets were unusually

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[8]It is possible that the flow of purchases may affect longer-term interest rates for reasons other than the effects on market functioning and liquidity, if the market faces other frictions.

[9]Another contributing factor to the high yield spreads is that many financial firms at that time faced constraints on their balance sheets, given the large capital losses on other assets and limited access to new funds. Capital constraints put agency-related debt at a disadvantage relative to Treasury securities, as agency-related holdings have a 20 percent risk weighting compared with 0 percent for Treasury securities.

[10]See Gürkaynak and Wright (2010, p. 56).

strained, the primary long-run effects are likely associated with the portfolio balance effect. The lack of significant movements in interest rates around the times that each component of the LSAP programs was wound down suggests that market functioning was no longer impaired and that the Federal Reserve presence in the market had little additional effect beyond that through its portfolio holdings.

3.   Implementation of LSAPs

The Federal Reserve holds assets that it has purchased in the open market in its System Open Market Account (SOMA). Historically, SOMA holdings have been nearly all Treasury securities, although small amounts of agency debt were held at times in the past.[11] Purchases and sales of SOMA assets are called outright open-market operations (OMOs). Outright OMOs, in conjunction with repurchase agreements and reverse repurchase agreements, traditionally were used to alter the supply of bank reserves in order to influence conditions in the federal funds market.[12] Most of the higher-frequency adjustments to reserve supply were accomplished through repurchase and reverse repurchase agreements, with outright OMOs conducted periodically to accommodate trend growth in currency demand.

OMOs generally were designed to have a minimal effect on the prices of the securities included in the operations. To that end, they tended to be small in relation to the markets for Treasury bills and Treasury coupon securities. LSAPs, on the other hand, aimed to have a noticeable impact on the interest rates of the assets being

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[11]Agency purchases were introduced in 1971 in order to "widen the base for System open market operations and to add breadth to the market for agency securities." New purchases were stopped in 1981, although some maturing funds from agency holdings were reinvested in newly issued agency securities. Beginning in 1997, all holdings of agency securities were allowed to mature without replacement. The last agency holding acquired under these programs matured in December 2003.

[12]A repurchase agreement is similar to a collateralized loan. The borrower sells a security to the lender and simultaneously promises to buy back the security at a fixed price. The Federal Reserve lends funds to the market through repurchase agreements in order to increase reserves. To withdraw funds, the Federal Reserve engages in repurchase agreements in the opposite direction, also known as "reverse repurchase agreements."

purchased as well as on other assets with similar characteristics. In order to achieve this goal, LSAPs were designed to be large relative to the markets for these assets. Between December 2008 and March 2010, the Federal Reserve purchased more than $1.7 trillion in assets. This represents 22 percent of the $7.7 trillion stock of longer-term agency debt, fixed-rate agency MBS, and Treasury securities outstanding at the beginning of the LSAPs.[13] Another way to scale the purchases is to measure the amount of duration they removed from the market using the concept of "ten-year equivalents," or the amount of ten-year par Treasury securities that would have the same duration as the portfolio of assets purchased. Between December 2008 and March 2010, the Federal Reserve purchased about $850 billion in ten-year equivalents. That represents more than 20 percent of the $3.7 trillion outstanding stock of ten-year equivalents across these three asset classes at the beginning of the programs.[14],[15] We believe that no investor—public or private—has ever accumulated such a large amount of securities in such a short period of time.

Purchases of agency debt were concentrated in medium-term securities because of the small outstanding supply at longer maturities (figure 1). Purchases of agency MBS were concentrated in newly issued low-coupon thirty-year securities issued by Fannie Mae and Freddie Mac (figure 2), which were relatively more liquid and had longer durations than other MBS. Purchases of Treasury securities

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[13]The outstanding stock is computed from Barclays Capital Indices, based on data for November 24, 2008 (the day before the initial announcement of LSAPs). The amount includes only fixed-rate issues with at least one year to final maturity, and at least $250 million par amount outstanding. The measure of agency debt outstanding includes debt issued by U.S. government agencies, quasi-federal corporations, and corporate or foreign debt guaranteed by the U.S. government (such as USAID securities), but the largest issues are from Fannie Mae, Freddie Mac, and the Federal Home Loan Bank System.

[14]The outstanding stock of ten-year equivalents is also computed from Barclays Capital Indices, based on data for November 24, 2008. Note that this measure of duration is affected by changes in the shape of the Treasury yield curve and by the level of interest rates through their effect on prepayment of MBS.

[15]Note that, in these calculations, we combine the purchases of all three asset types, as they all remove duration from the market and hence should affect risk premiums on all assets with duration exposure. In the regression analysis in section 4, we focus on the net supply of long-term assets by the public sector because this measure plausibly may be assumed to be exogenous with respect to risk premiums. We thus ignore privately issued long-term assets that are held by private investors.

Figure 1. Distribution of Agency Debt Purchases by Maturity
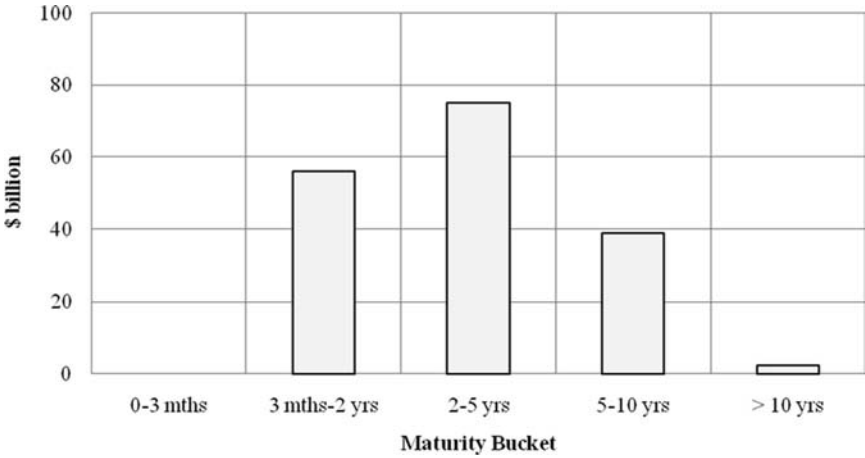
Source: Federal Reserve Bank of New York.

Figure 2. Distribution of MBS Purchases by Coupon
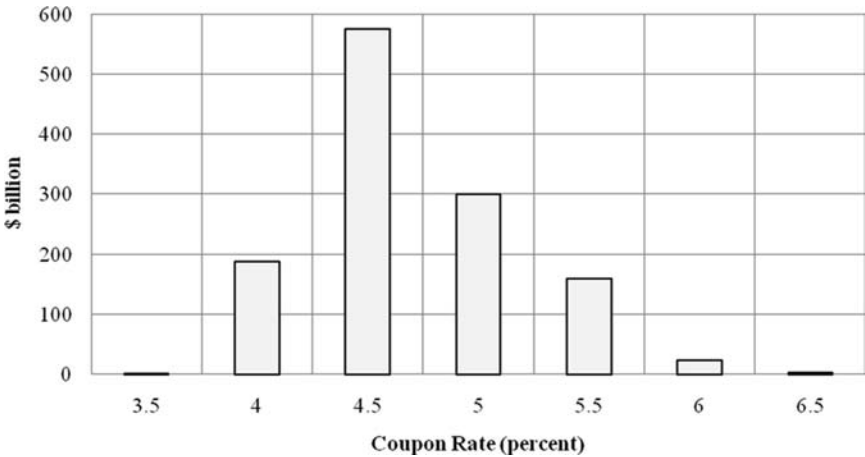
Source: Federal Reserve Bank of New York.

Figure 3. Distribution of Treasury Purchases by Maturity

Source: Federal Reserve Bank of New York.

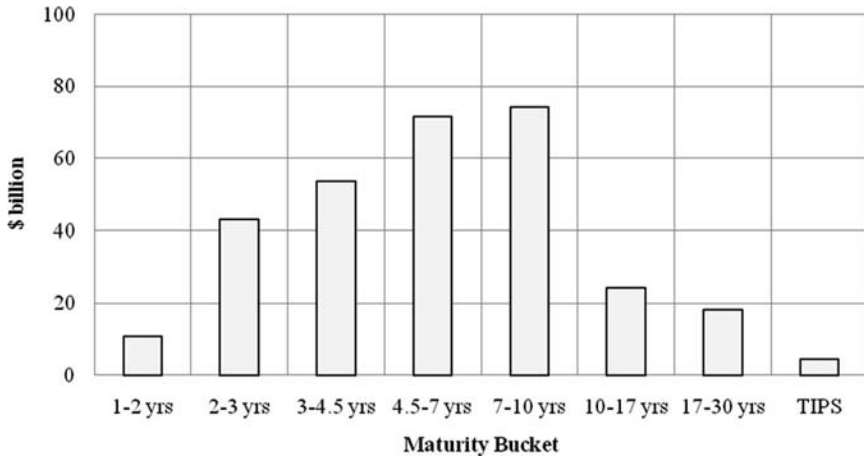were concentrated in the two- to ten-year maturity sectors (figure 3). Nevertheless, there were significant amounts purchased outside of these targeted sectors, including a range of maturities of Treasury debt and higher-coupon seasoned agency MBS, in order to avoid substantial distortions in the yield curves and spreads on these assets. As noted earlier, purchases of agency debt and MBS began at a time when liquidity in these markets was poor and spreads to Treasury yields were unusually wide. In these circumstances, LSAPs appeared to improve market liquidity. Spreads of agency debt and MBS yields narrowed relative to Treasury yields, and spreads between on-the-run and off-the-run Treasury securities also narrowed.

The pace of purchases evolved fairly smoothly over the course of the program. Total purchases ranged between $50 and $200 billion on a monthly basis (figure 4). Purchases were somewhat heavier from March 2009 through June 2009, reflecting the expansion of the LSAP programs at that time and the large amount of MBS purchases made to offset heavy origination activity. The decision to taper purchases led to a slowing pace of purchases after the middle of 2009.[16]

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[16]The decision to gradually slow the pace of Treasury purchases was announced in the August 2009 FOMC statement. The decision to gradually slow the pace of agency purchases was announced in the September 2009 FOMC statement.

Figure 4. Pace of Purchases by Asset Class
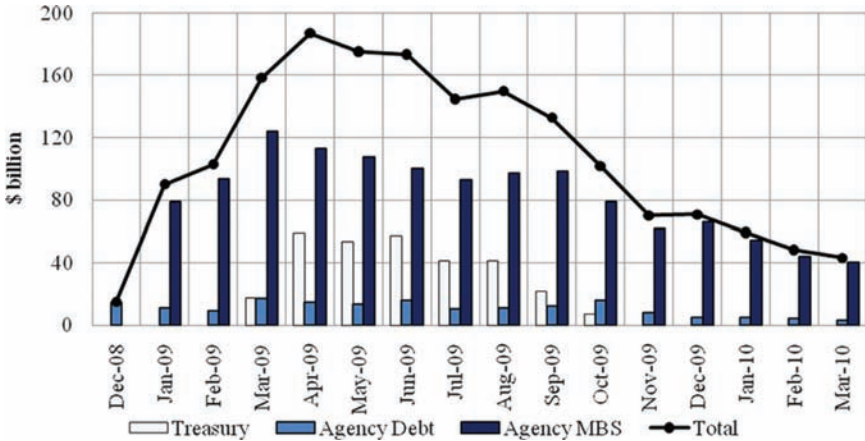
The Federal Reserve released a press statement shortly after the initial announcement of each program providing further details about the timing and overall structure of each program. Documents providing answers to frequently asked questions were released at the start of each program. These documents provided details as to what types of securities were eligible for purchase and what investment strategy would be employed, and they were updated to reflect changes in the programs, such as the increase in the targeted size of the agency debt and MBS programs or the inclusion of on-the-run securities for purchase in the agency debt program.

4.   Estimates of LSAP Effects

4.1   Other Studies

According to the expectations theory of the term structure, altering the maturity of the net supply of assets from the government to private investors should have only minimal effects on the term structure of interest rates. This view was supported by the literature studying Operation Twist in the early 1960s, which did not

find robustly significant effects of a swap between short-term and long-term Treasury securities in the SOMA portfolio.[17] However, as noted by Solow and Tobin (1987), Federal Reserve purchases during Operation Twist were small and were soon more than offset by increased Treasury issuance of long-term debt. Overall, there was little movement in the average maturity of Treasury debt held by the public and thus little hope of estimating a statistically significant and robust effect.

Subsequent time-series studies, using longer spans of data, generally have found a noticeable effect of shifts in the maturity structure of Treasury debt on the term structure.[18] The estimated size of this effect depends on the degree of theoretical restrictions imposed on the estimating equation. Tighter restrictions implied by simple models of household behavior generally lead to smaller estimates, but these restrictions typically are rejected statistically in favor of less restrictive specifications. Other time-series studies, while not focusing on the maturity structure of public debt, have found that increases in the total supply of public debt tend to raise longer-term interest rates.[19] Kozicki, Santor, and Suchanek (2010) analyze time-series data on the size of central bank balance sheets and find that increases in the balance sheet are associated with declines in long-term forward interest rates. Stroebel and Taylor (2009) find little effect of daily Federal Reserve purchases on the spread between MBS yields and swap yields and a moderate effect on the spread between MBS yields and Treasury yields.

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[17]See, for example, Modigliani and Sutch (1967). The current program differs from Operation Twist in that the reduction in long-term bonds is financed by reserve creation rather than sales of short-term Treasury bills. However, with interest rates on bank reserves and short-term bills roughly equal in the current environment, the two assets should be viewed as close substitutes and thus the effect on the term spread should be similar.

[18]All of the studies focused on the United States. See Friedman (1981), Frankel (1985), Agell and Persson (1992), Kuttner (2006), and Greenwood and Vayanos (2010). Since the original draft of this paper was written, Hamilton and Wu (2010) estimated the model of Vayanos and Vila (2009) and obtained results broadly similar to ours.

[19]See Gale and Orszag (2004), Engen and Hubbard (2005), and Laubach (2009). Warnock and Warnock (2009) also find that purchases of U.S. debt by foreign governments tend to lower U.S. long-term interest rates.

Bernanke, Reinhart, and Sack (2004) adopt an alternative approach to time-series analysis. They examine specific news events concerning future Treasury issuance or purchases of longer-term securities and find that longer-term yields dropped significantly on days in which the market learned of future declines in the net supply of longer-term Treasury securities.

Since the original draft of this paper was written, two new papers have focused on the effects of the LSAPs. Neely (2010) uses the event-study methodology and shows that Federal Reserve announcements concerning LSAPs had significant effects on U.S. and foreign bond yields and on exchange rates. D'Amico and King (2010) use cross-section data on yields on all outstanding Treasury securities. They find that yields on securities purchased in the LSAP program fell more than yields on securities that were not purchased. Their model allows for own-price and cross-price effects on yields and they conclude that the program substantially reduced medium- and long-term Treasury yields. In addition to this permanent effect, they also find a small temporary effect of the flow of Federal Reserve purchases on yields.

In this paper, we employ both time-series and event-study methodologies to gauge the overall effects of the LSAP programs.

4.2   An Event Study of Recent LSAP Communications

In this section we use an event-study analysis of Federal Reserve communications to derive estimates of the effects of LSAPs. In particular, we examine changes in interest rates around official communications regarding asset purchases, taking the cumulative changes as a measure of the overall effects. In doing so, we implicitly assume that (i) our event set includes all announcements that have affected expectations about the total future volume of LSAPs, (ii) LSAP expectations have not been affected by anything other than these announcements, (iii) we can measure responses in windows wide enough to capture long-run effects but not so wide that information affecting yields through other channels is likely to have arrived, and (iv) markets are efficient in the sense that all the effects on yields

occur when market participants update their expectations and not when actual purchases take place.[20]

The financial variables we examine are the two-year and ten-year Treasury yields, the ten-year agency debt yield, the current-coupon thirty-year agency MBS yield, the ten-year Treasury term premium (based on Kim and Wright 2005), the ten-year swap rate, and the Baa corporate bond index yield.[21] Swap rates and corporate bond yields help us to gauge the extent to which news about LSAPs affected yields on assets that were not purchased by the Federal Reserve.

We focus on a narrow set of official communications, each of which contained new information concerning the potential or actual expansion of the size, composition, and/or timing of LSAPs. The eight announcements included in this "baseline" event set are as follows:

- the initial LSAP announcement on November 25, 2008, in which the Federal Reserve announced it would purchase up to

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[20]These are strong assumptions. The need for them arises in part because we do not have a direct measure of expectations about the size of future LSAPs. With such a measure, we could use announcements to identify exogenous shocks to LSAP expectations. The corresponding yield responses could then be used to derive statistical estimates of the effects of changes in expectations and, from these, the total effects of LSAPs could be extrapolated. Such an approach is typical of studies of the effects of surprise changes to the target federal funds rate, using interest rate futures contracts to measure market expectations. A particular challenge in isolating the effects of LSAPs is that the announcements we identify are likely to have contained non-LSAP information relevant to yields, including policy measures and updates to the FOMC's economic outlook. As a result, it is impossible to draw a response window narrow enough to include only the effects of LSAPs.

[21]We measure agency debt yields using Freddie Mac's on-the-run fixed-rate senior benchmark non-callable note; as of February 1, 2010, Fannie Mae had not issued a ten-year note since 2007. On-the-run agency debt was not included in LSAPs until September 2009, but the cumulative changes in the first off-the-run yield are almost identical to the changes in the on-the-run yield. The MBS yield is the average of the Freddie Mac and Fannie Mae current-coupon thirty-year agency MBS yields. The interest rates are from Bloomberg, except for the Baa yield, which is from Barclays Capital. The Kim-Wright term premium data are made available by the Federal Reserve Board at www.federalreserve.gov/econresdata/researchdata.htm. The Kim-Wright term premium is based on implied zero-coupon yields on off-the-run securities, whereas the Treasury yield series are for on-the-run coupon securities.

$100 billion in agency debt and up to $500 billion in agency MBS;

- Chairman Bernanke's December 1, 2008 speech, in which he stated that in order to influence financial conditions, the Federal Reserve "could purchase longer-term Treasury securities. . . in substantial quantities";
- the December 2008 and January 2009 FOMC statements, which indicated that the FOMC was considering expanding purchases of agency securities and initiating purchases of longer-term Treasury securities;
- the March 2009 FOMC statement, in which the FOMC announced the decision to purchase "up to" $300 billion of longer-term Treasury securities and to increase the size of agency debt and agency MBS purchases to "up to" $200 billion and $1.25 trillion, respectively;
- the August 2009 FOMC statement, which dropped the "up to" language qualifying the maximum amount of Treasury purchases and announced a gradual slowing in the pace of these purchases;
- the September 2009 FOMC statement, which dropped the "up to" language qualifying the maximum amount of agency MBS purchases and announced a gradual slowing in the pace of agency debt and MBS purchases; and
- the November 2009 FOMC statement, which stated that the FOMC would purchase "around $175 billion of agency debt."

We consider the response of interest rates using one-day windows around the announcements, measured from the closing level the day prior to the announcement to the closing level the day of the announcement.[22] Selecting the window length involves a trade-off between allowing sufficient time for revised expectations to become fully incorporated in asset prices and keeping the window narrow enough to make it unlikely to contain the release of other important information. Although event studies often examine *intraday* price changes in order to avoid the pollution of measured responses by

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[22]We use the two-day change for the MBS yield around the March 2009 FOMC meeting because of an error in the Bloomberg MBS yield series on March 18. As discussed below, we also tried using two-day windows for all event days and interest rates.

Table 1. Interest Rate Changes around Baseline and Extended Event Set Announcements

Date	Event	2y UST	10y UST	10y Agy	Agy MBS[b]	10y TP	10y Swap	Baa Index
11/25/2008[a]	Initial LSAP Announcement	−2	−22	−58	−44	−17	−29	−18
12/1/2008[a]	Chairman Speech	−8	−19	−39	−15	−17	−17	−12
12/16/2008[a]	FOMC Statement	−9	−26	−29	−37	−12	−32	−11
1/28/2009[a]	FOMC Statement	10	14	14	11	9	14	2
3/18/2009[a]	FOMC Statement	−22	−47	−52	−31	−40	−39	−29
4/29/2009	FOMC Statement	1	10	−1	6	6	8	−3
6/24/2009	FOMC Statement	10	6	3	2	4	4	5
8/12/2009[a]	FOMC Statement	−2	5	4	2	3	1	2
9/23/2009[a]	FOMC Statement	1	−3	−3	−1	−1	−5	−4
11/4/2009[a]	FOMC Statement	−2	6	8	1	5	5	3
12/16/2009	FOMC Statement	−2	1	0	−1	1	1	−1
1/27/2010	FOMC Statement	11	3	4	4	1	3	1
3/16/2010	FOMC Statement	−3	−5	−4	−4	−4	−4	−5
1/6/2009	Minutes Release	0	−4	3	−17	−1	−9	−14
2/18/2009	Minutes Release	9	11	4	6	8	9	16
4/8/2009	Minutes Release	2	−4	−7	−9	−4	−6	−6
5/20/2009	Minutes Release	−5	−5	−5	−7	−4	−4	−10
7/15/2009	Minutes Release	7	13	16	16	10	16	7
9/2/2009	Minutes Release	−1	−6	−6	−4	−7	−8	−5
10/14/2009	Minutes Release	1	7	10	3	7	7	8
11/24/2009	Minutes Release	0	−5	−5	−9	−5	−6	−3
1/6/2010	Minutes Release	−2	6	5	4	6	7	−1
2/17/2010	Minutes Release	4	7	7	8	6	8	5
Baseline Event Set		*−34*	*−91*	*−156*	*−113*	*−71*	*−101*	*−67*
Baseline Set + All FOMC		*−1*	*−55*	*−134*	*−114*	*−47*	*−75*	*−72*
Cumulative Change: *11/24/08 to 3/31/2010*		*−19*	*50*	*−75*	*−95*	*30*	*28*	*−489*
Std Dev of Daily Changes: *11/24/08 to 3/31/10*		*5*	*8*	*9*	*10*	*6*	*9*	*7*

[a]Included in the baseline event set.
[b]Two-day change for agency MBS on March 18, 2009 due to a Bloomberg data error.

extraneous information, we believe a wider window is suitable in this context. Specifically, given the novelty of the LSAPs and the diversity of beliefs about the mechanisms by which they operate, changes may have been absorbed more slowly than for typical monetary policy shocks (such as those to the target federal funds rate).

Table 1 displays the changes in interest rates on each day in the baseline event set described above as well as on days in which the

**Figure 5. Cumulative Interest Changes on Baseline
Event Set Days**
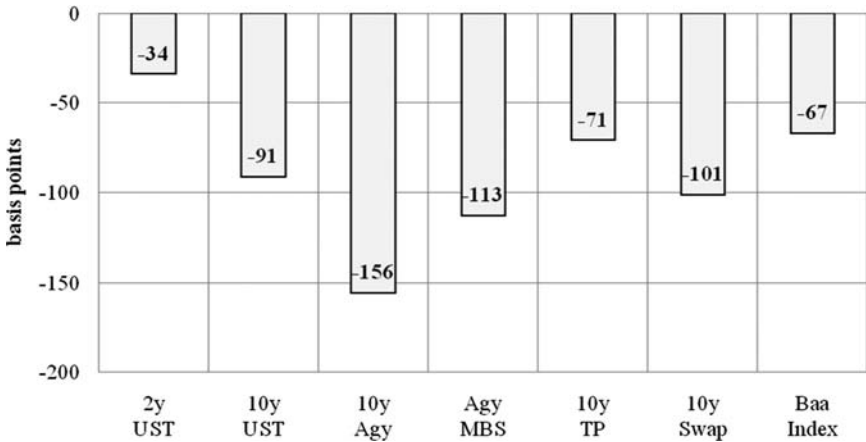
Source: Bloomberg, Barclays Capital.

FOMC issued communications concerning the LSAPs that provided little new information. Figure 5 displays the cumulative changes in interest rates across the eight announcements in the baseline event set. All interest rates declined notably, with the ten-year Treasury yield, ten-year agency debt yield, and current-coupon agency MBS yield declining 91, 156, and 113 basis points, respectively. The large change in the ten-year Treasury yield relative to the two-year Treasury yield suggests that the announcements reduced longer-term rates principally by reducing the term premium, as opposed to signaling a commitment to keep policy rates low for an extended period of time. This inference is confirmed by the large cumulative drop in the Kim-Wright ten-year term premium measure. The relatively large changes in agency debt and agency MBS yields demonstrate that the LSAPs also helped to lower spreads of the yields on these assets relative to those on Treasury securities. The substantial declines in the swap rate and the Baa corporate bond yield show that LSAPs had widespread effects, beyond those on the securities targeted for purchase.

Some observers, noting that the ten-year Treasury yield did not decline on net over the course of the LSAP programs, have argued

**Figure 6. Cumulative Changes since November 2008,
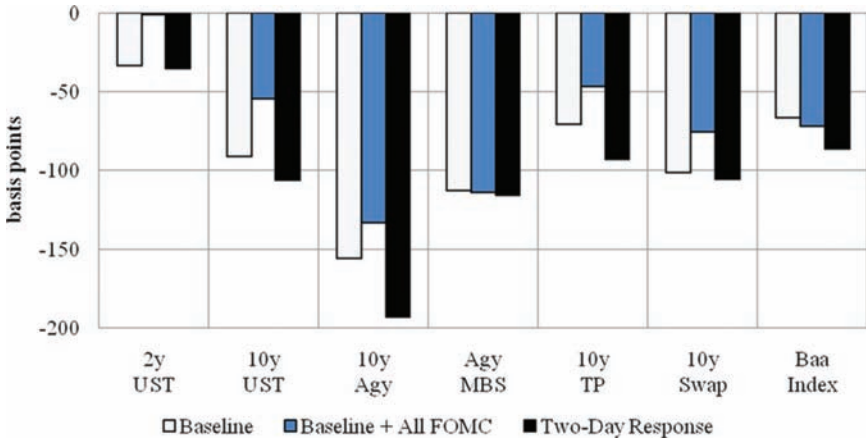Event vs. Non-Event Days**
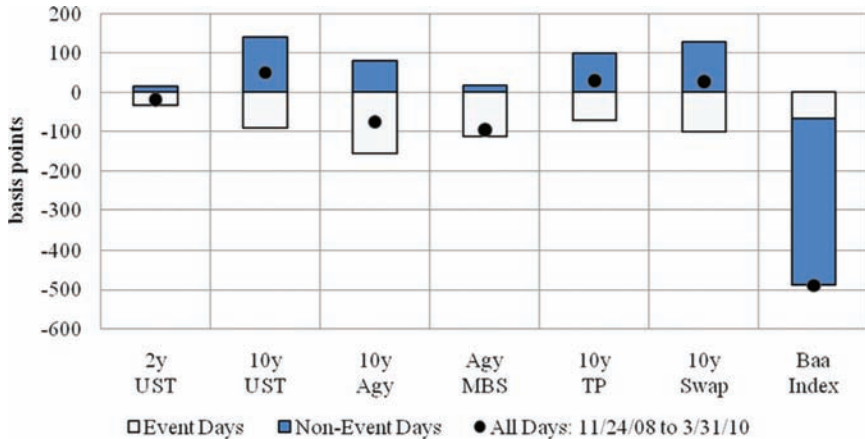
Source: Bloomberg, Barclays Capital.

that the LSAPs did not have a lasting effect. Figure 6 compares the
net changes in interest rates on the baseline event days with the net
changes on all other days from November 24, 2008 through March
31, 2010. The ten-year Treasury yield and swap rate increased more
than 100 basis points on non-event days, and hence were up mod-
erately over the entire period. However, there were many factors at
play that would have been expected to lift Treasury yields over that
period, including a very large increase in the expected future fiscal
deficit, a significant rebound in the economic outlook, and a sharp
reversal of the flight-to-quality flows that had occurred in the fall
of 2008.[23] It is likely those factors, and not a reversal of the effects
of the LSAP announcements, that drove Treasury yields higher on
other days. Supporting that view, other interest rates showed very

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[23]On December 10, 2008, the Blue Chip Economic Indicators survey average
projection of the fiscal year 2009 federal deficit was $672 billion. In January
2010, the Congressional Budget Office estimated the 2009 deficit at $1587 billion
and projected the 2010 deficit at $1381 billion. The Conference Board's Index of
Leading Economic Indicators rose from 99.2 in November 2008 to 109.4 in March
2010.

**Figure 7. Cumulative Interest Rate Changes
around Announcement Events, Alternative
Event-Study Parameters**

Source: Bloomberg, Barclays Capital.

different patterns than that of the ten-year Treasury yield on non-event days. The agency debt yield rose less than the Treasury yield, the MBS yield was little changed, and the Baa corporate bond yield dropped about 400 basis points. This combination of a rising Treasury yield and a falling corporate bond yield is consistent with the relaxation of the extreme financial strains and flight to quality that characterized the early part of 2009, and it highlights the importance of focusing on event days to measure the effects of LSAPs separately from the effects of other developments.

Finally, figure 7 plots cumulative interest rate changes using two modifications to our event study. In the first, we continue to use one-day response windows but expand the event set to include all FOMC statements and minutes between November 2008 and January 2010 to allow for the possibility that markets gleaned information about the future of LSAPs from these communications. In the second, we use the same baseline event set as above but extend the response window to two days to allow for lagged reactions to the news by some market participants. Most of the measured effects of the LSAPs change only modestly using these alternative parameterizations of the event study. Using the expanded event set, the

cumulative declines are between 10 basis points larger and 30 basis points smaller than with the baseline set. The smaller declines may reflect that markets had attributed some probability to further increases in the LSAPs and that these expectations were adjusted downward when the FOMC did not move in that direction on the non-baseline event days. On the other hand, using two-day response windows, the cumulative declines are 0 to 40 basis points larger than with the one-day windows, suggesting that it may have taken more than one day for the market to fully adjust to these communications.[24]

To more carefully evaluate whether the effects found above arose through the term premium, as would be expected from the theoretical discussion in section 2, we focus on yield movements around the two FOMC announcements that also contained new language on the prospects for future short-term interest rates. In particular, on December 16, 2008, the FOMC stated its view that the federal funds rate was likely to remain at "exceptionally low levels for some time." On March 18, 2009, the FOMC modified this language to "exceptionally low levels for an extended period." We want to make sure that the yield movements around those dates do not reflect a decline in expected future short-term interest rates associated with those statements.

One way to approach this issue is to rely on the Kim-Wright estimated term premium used above to examine the market interest rates with maturities that are most likely to be affected by the FOMC statements concerning the future federal funds rate. Any movement in the expected federal funds rate at these horizons is likely to be much greater than the average movement in the expected federal funds rate over the next ten years. We focus on the movement in the estimated one-year-ahead instantaneous interest rate around the release of the FOMC statements.[25] According to the Kim-Wright estimates, the one-year-ahead expected instantaneous interest rate dropped only 4 basis points on December 16, 2008 and then rose

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[24]MBS yields, in particular, may have taken longer to respond fully to these communications. Adding a third day to the windows increases the cumulative decline of MBS yields by more than 30 basis points, whereas it has little effect on the cumulative declines in the other yields.

[25]The instantaneous interest rate is a construct of the Kim-Wright model that is essentially equivalent to the federal funds rate.

16 basis points the following day.[26] An alternative gauge of market expectations is the one-year-ahead forward instantaneous interest rate, as the term premium would presumably be limited in size at this horizon.[27] This rate dropped 11 basis points on December 16 but then rose 17 basis points the following day.

On March 18, 2009, the Kim-Wright one-year-ahead expected instantaneous interest rate dropped 4 basis points and rose by the same amount on the following day.[28] The one-year-ahead forward instantaneous rate dropped 28 basis points on March 18, but about half of this decline was unwound over the next few days. Overall, these observations on expected future and forward interest rates suggest that the December 2008 and March 2009 FOMC statements did not have large effects on market expectations of the future path of the federal funds rate—certainly not enough to explain the substantial decline in longer-term interest rates on those days.[29]

In principle, the LSAP programs could have raised the expected future path of the federal funds rate by accelerating the expected pace of economic recovery. In this case, the LSAP effect on the term premium would be greater than the effect on the long-term Treasury yield. According to table 1, however, the LSAP effects on the ten-year Treasury yield are slightly larger than those on the ten-year term premium, suggesting that LSAPs did not raise the expected future federal funds rate.

Altogether then, we find that longer-term interest rates declined by up to 150 basis points around key LSAP announcements. Moreover, the majority of the decline in the ten-year Treasury yield around these announcements can be attributed to declines in the term premium. Figure 7 shows that, depending on the event set

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[26]The two-year-ahead expected instantaneous interest rate dropped 6 basis points on December 16 and rose 4 basis points on December 17.

[27]The forward rate is the sum of the expected future instantaneous rate and the forward term premium. It can be derived directly from the yield curve without requiring any modeling of, or assumptions about, its components beyond those required to fit a yield curve to observed bond yields.

[28]The two-year-ahead expected instantaneous interest rate dropped 14 basis points on March 18 and rose 3 basis points on March 19.

[29]It is possible that these FOMC statements affected the term premium directly by reducing uncertainty about the path of future interest rates. Estimating this effect is beyond the scope of this paper, but we believe such effects are likely to have been small.

and response window used, LSAP announcements reduced the ten-year term premium by between 50 and 100 basis points. Little of the observed declines in longer-term yields appears to reflect declining expectations of future short-term interest rates associated with FOMC communications about the likely future path of the federal funds rate.

4.3   Time-Series Analysis of Longer-Term Treasury Supply

In this section, we use a different method and different data to measure the impact of asset purchases (or sales) on the ten-year term premium.[30] Specifically, we estimate statistical models that explain the historical variation (prior to the announcement of the LSAP programs) in the term premium using factors related to (i) the business cycle, (ii) uncertainty about economic fundamentals, and (iii) the net public-sector supply of longer-term dollar-denominated debt securities. Using a variety of model specifications, we estimate the effects of changes in the stock of longer-term debt held by private investors on the term premium. We then use these results to estimate the (out-of-sample) impact of the Federal Reserve's asset purchases, which represent a reduction in the supply of longer-term debt securities to private investors.

Following Backus and Wright (2007), we explain historical time variation in the term premium using an ordinary least squares regression model of the form

$$tp_t^{10} = X_t\beta + \varepsilon_t,$$

where tp_t^{10} is the nominal ten-year yield term premium, and X_t is a set of observable factors.[31] However, we expand on the set of

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[30]The term premium likely captures the largest component of the LSAPs' effects on private borrowing rates. However, as we highlighted in section 2, LSAPs also affected other components of risk premiums. The statistical models here do not attempt to estimate these other effects or the effects on term premiums at different horizons.

[31]Whereas Backus and Wright modeled the instantaneous *forward term premium* ten years ahead, we focus on the ten-year *yield term premium* because of our interest in the purchases' effects on longer-term interest rates.

explanatory variables used by Backus and Wright, focusing on the three types of variables noted above.[32]

In particular, the following variables are included to capture term premium variation related to the business cycle and fundamental uncertainty:

- *Unemployment gap*: measured as the difference between the unemployment rate and the Congressional Budget Office's estimate of the natural rate of unemployment.
- *Core CPI inflation*: a second measure of the macroeconomic state, the twelve-month change in core CPI, may also proxy for inflation uncertainty.[33]
- *Long-run inflation disagreement*: measured as the interquartile range of five- to ten-year-ahead inflation expectations, as reported by the Michigan Survey of Consumers.[34]
- *Six-month realized daily volatility of the on-the-run ten-year Treasury yield*: a proxy for interest rate uncertainty. We use this instead of option-implied volatility because it is available over a longer period.[35]

To capture the effects of changes in the net public-sector supply of longer-term debt securities, we use the following time series, each of which is expressed as a percent of nominal GDP:

- publicly held Treasury securities with at least one year to maturity, including securities held by private investors as well as those held by the Federal Reserve and by foreign official institutions;

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[32]In early analysis we also included a measure of the on-the-run Treasury liquidity premium as a proxy for the "flight-to-quality" demand for Treasuries. However, the coefficient on this term was never significant, and excluding it did not affect the magnitude or significance of the other coefficients. For ease of exposition, we omit it here.

[33]Mankiw, Reis, and Wolfers (2004) show that inflation disagreement, the level of inflation, the absolute value of the change in inflation, and relative price variability positively co-vary.

[34]We use the Michigan survey because of its long history and relatively high frequency (monthly), but our results are not significantly affected if we use long-run inflation disagreement taken from the Blue Chip Economic Indicators survey instead. The Michigan survey did not include the long-run inflation question during some months during the 1980s. We linearly interpolate the series where data are missing.

[35]Realized and implied volatility are highly correlated at the monthly frequency, and our modeling choice does not appear to substantively alter the results.

- Treasury securities held in the Federal Reserve's SOMA portfolio with at least one year to maturity;[36] and
- U.S. debt securities held by foreign official agencies, with at least one year to maturity. This measure includes Treasury securities, agency-related securities, and corporate bonds, and is interpolated from annual stock surveys, using monthly Treasury International Capital (TIC) flows, by the Board of Governors of the Federal Reserve System.[37]

An important assumption of our statistical analysis is that these longer-term debt stock variables are exogenous with respect to the term premium. For example, this assumption implies that the Treasury does not issue more long-term debt when the term premium declines. To the extent that these public-sector agencies do respond to term premiums in a manner similar to private investors—that is, by buying more long-term debt (or selling less long-term debt) when the term premium is high—our estimates of the effect of public-sector longer-term debt supply on the term premium will be biased downward. Overall, we believe it is reasonable to assume that these public agencies respond very little to term premiums. However, our estimates may be viewed as somewhat conservative owing to this potential downward bias.

The response of private investors to the net public-sector supply of assets should not be affected by the specific public-sector agency doing the purchases or sales. Thus, when the Treasury buys back a longer-term security, it should have the same effect on longer-term yields as when the Federal Reserve buys that security or when a foreign official agency buys that security (assuming that each is expected to hold the security on a persistent basis and controlling for any policy signals the purchases convey). Moreover, the term premium should be roughly equally affected by public-sector purchases of either Treasury securities or agency-related securities with similar durations. Accordingly, the appropriate measure of the net supply of longer-term debt securities by the public sector would include

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[36]As noted above, the SOMA held agency securities between 1971 and 2003. However, these were a very small portion of total SOMA holdings (less than 5 percent), and information on the maturity and duration of these holdings is not available.

[37]See Bertaut and Tryon (2007). The data are available at www.federalreserve.gov/pubs/ifdp/2007/910/default.htm.

longer-term Treasury securities less the total amount of longer-term debt held by the SOMA and by foreign official institutions.[38] We estimate models with this measure of the net supply of longer-term debt expressed in both unadjusted terms and as ten-year Treasury equivalents.[39] The duration adjustment captures relevant variation in the *composition* of the outstanding stock of debt securities.[40]

We estimate the model on monthly data over the period January 1985 to June 2008. This period was selected because it is the full sample over which data on each of the variables is available, and because it ends shortly before the initial announcement of asset purchases in the fall of 2008. The first two columns of table 2 present results from a regression of the ten-year term premium on the explanatory variables, using the unadjusted net debt stock measure. The third and fourth columns present results using the duration-adjusted net debt stock. For comparison, in this and subsequent tables, we include estimates from the model without any debt supply variable in the final columns.

The results are similar with either measure of the debt stock. The explanatory variables are almost all significant at the 1 percent level and always have the expected sign. Specifically, 1-percentage-point increases in the unemployment gap, core CPI inflation, inflation disagreement, and realized volatility increase the term premium about 20, 30, 40, and 100 basis points, respectively. As for the supply variables, a 1-percent-of-GDP increase in longer-term debt supply

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[38]We do not include privately issued debt securities held by private investors because these securities have a net zero supply from the point of view of the private sector, and because demand and supply for them are likely not exogenous with respect to the term premium.

[39]The unadjusted stock of Treasury securities with remaining maturity greater than one year is obtained from table FD-5 of the *Treasury Bulletin*. This table excludes SOMA holdings but includes foreign official holdings, which we subtracted using the TIC data described above. The duration-adjusted stock of non-SOMA Treasuries comes from Barclays Capital and, unlike the unadjusted measure, excludes Treasury Inflation-Protected Securities (TIPS). In the duration-adjusted regressions we use foreign holdings of long-term Treasury securities only (i.e., not agency-related securities or corporate bonds) and assume that these have the same duration as non-SOMA Treasuries held by the public. Because we cannot isolate foreign holdings of TIPS, the adjusted stock variable may understate holdings (by subtracting TIPS holdings from a total stock measure that already excludes it). The effect should be minor.

[40]As described in section 2, the adjustment converts the amount, S, into an amount of ten-year Treasury securities with the same portfolio duration: ten-year equivalents = $S * \text{duration}(S)/\text{duration}(10y)$.

Table 2. OLS Regression of Ten-Year Term Premium, January 1985–June 2008

	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
Constant	−2.182***	0.348	−2.324***	0.349	−1.852***	0.334
Cyclical Factors						
Unemployment Gap	0.180**	0.064	0.185**	0.063	0.252***	0.070
Core CPI	0.307***	0.056	0.298***	0.057	0.480***	0.062
Uncertainty						
Inflation Disagreement	0.377**	0.131	0.394**	0.133	0.286*	0.123
Realized Volatility	0.943***	0.207	0.994***	0.206	0.944***	0.271
Supply						
Unadjusted	0.044***	0.009	—		—	
Duration-Adjusted	—		0.064***	0.014	—	
Adjusted R-squared	0.84		0.84		0.78	
Standard Error of Regression	0.36		0.37		0.43	
Number of Observations	282		282		282	

Notes: Newey West standard errors (twelve lags). ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

increases the ten-year term premium by 4.4 basis points on an unadjusted basis and 6.4 basis points when expressed in terms of ten-year Treasury equivalents.[41] Both coefficients are statistically significant at the 1 percent level.[42]

The $1.725 trillion in purchases by the Federal Reserve is roughly 12 percent of 2009 nominal GDP, which, according to the estimates in the first column, implies that total Federal Reserve asset purchases reduced the term premium by 52 basis points. In terms of ten-year equivalents, the Federal Reserve purchased a total of approximately $850 billion—roughly 6 percent of 2009 nominal GDP—which, according to estimates in the third column, would imply that asset purchases reduced the term premium by 38 basis points.

None of the variables included in the model can grow or decline without bound, and thus there is a strong presumption that they are stationary. However, some of them may have a sufficiently large autocorrelation to appear non-stationary within our twenty-three-year estimation sample. Thus, we also use dynamic ordinary least squares (DOLS) based on Stock and Watson (1993) to estimate the long-run relationship (also known as the cointegrating vector) between the term premium and the explanatory variables. In addition to the levels of our explanatory variables, the contemporaneous, lead, and lagged first differences of each are included as regressors.[43]

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[41]We cannot reject that the debt stock coefficients are constant between the first and second halves of the sample.

[42]If the debt stock components—Treasury, SOMA, and TIC—are entered separately into the regression, the coefficients on SOMA and TIC are a bit larger and the coefficient on Treasury is considerably smaller than the coefficient on the combined variable. We suspect that the smaller separate Treasury estimate arises because shifts in the supply of long-term Treasury securities are anticipated far in advance. In the regressions reported here we nevertheless impose the assumption that the effects are the same.

[43]The following procedure was used to select the leads and lags included within the DOLS regression. We start with a single lead and lag of the first difference of each explanatory variable. If the lead or lag for a variable was statistically significant at the 5 percent level (using Newey-West standard errors with twelve lags), we added one more, and removed all leads and lags that were not significant. If the added lead or lag was still significant, we added four more. For each specification this was enough to make the leads and lags of the longest length statistically insignificant. For robustness, we also estimated the model using six leads and lags of the first differences. The coefficient estimates on supply in the cointegrating vectors were virtually unchanged from those derived according to the selection procedure just described.

The level coefficients from the DOLS regression estimate the long-run relationship between the variables, and the deviation of the term premium from this long-run relationship is referred to as the cointegration error. Regressing the change in the term premium on the contemporaneous change in the explanatory variables and on the lagged level of the cointegration error allows us to estimate the long-run adjustment speed of the cointegrating relationship and to test the significance of the cointegrating relationship.

The first two columns of table 3 present results from the DOLS model, again estimated over the period January 1985 to June 2008. The long-run effects of changes in the longer-term debt stock are almost identical to those obtained in table 2. Specifically, an increase in longer-term debt equal to 1 percent of GDP increases the term premium by just over 4 basis points in the unadjusted specification and by just over 6 basis points in the duration-adjusted specification. The adjustment speed parameters of −0.15 imply that deviations in the term premium from long-run equilibrium have a half-life of roughly five months. The t-statistics on the adjustment speeds are −5.7 and −6.3, which are sufficiently large to reject the hypothesis that these variables do not have a stable long-run relationship (that is, they are not cointegrated) at the 1 percent significance level. Note that the adjustment speed drops substantially when the debt stock variables are excluded (the final columns), suggesting that the longer-term debt stock is an important part of the long-run relationship.

The preceding regressions are based on the Kim-Wright model of the ten-year term premium, which was estimated over a sample that does not include a major financial crisis or monetary policy constrained by the zero bound on nominal interest rates. As a robustness check, we also estimate a specification that uses the ten-year Treasury yield as the dependent variable and that includes the target federal funds rate and the slope of the near-term Eurodollar futures curve to proxy for the expected path of policy rates.[44] Under the assumption that the two additional variables adequately control for expected future policy interest rates, the estimated coefficients on

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[44]Specifically, we use the difference between the implied rates on Eurodollar futures contracts settling approximately two years and one year ahead.

Table 3. Dynamic OLS Regression of Ten-Year Term Premium, January 1985–June 2008

	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
Constant	−2.288***	0.388	−2.351***	0.425	−1.879***	0.355
Cyclical Factors						
Unemployment Gap	0.222***	0.062	0.219***	0.063	0.283***	0.071
Core CPI	0.302***	0.065	0.281***	0.063	0.502***	0.067
Uncertainty						
Inflation Disagreement	0.458**	0.173	0.454*	0.180	0.292	0.152
Realized Volatility	0.822***	0.221	0.901***	0.229	0.867**	0.296
Supply						
Unadjusted	0.042***	0.008	—	—	—	—
Duration–Adjusted	—	—	0.062***	0.014	—	—
Long-Run Properties						
Adjustment Parameter[a]	−0.154***	0.03	−0.151***	0.024	−0.116***	0.021
ADF Test on Coint. Error[b]	−6.051***		−5.957***		−3.441**	
Number of Observations	282		280		282	

Notes: Newey West standard errors (twelve lags). ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.
[a]Estimated by regressing the change in the term premium on the contemporaneous change in each explanatory variable and on the lagged level of the cointegration error.
[b]Null hypothesis: no cointegrating relationship.

the other variables should continue to reveal their impact on the ten-year term premium. Note that another reason for focusing directly on the behavior of the ten-year yield is that the ultimate goal of LSAPs is to lower longer-term private borrowing rates, many of which are highly correlated with ten-year Treasury yields. As the first and third columns of table 4 show, the estimated longer-term debt supply effects are somewhat higher in this specification than in the term premium regressions. The estimated coefficients of 0.07 and 0.10 on the unadjusted and duration-adjusted debt stocks imply that LSAPs have reduced the ten-year term premium by 82 basis points (unadjusted model) or 58 basis points (duration-adjusted model).[45]

Table 5 summarizes the estimated coefficients on longer-term debt stock across our specifications and lists the implied effects of the Federal Reserve's asset purchases on the ten-year term premium. Our results suggest that the $1.725 trillion in announced purchases reduced the ten-year term premium by between 38 and 82 basis points. This range of point forecasts overlaps considerably with that obtained in our event study, which is impressive given that entirely separate data and methodologies were used to obtain the results.[46]

5.   Experiences of Other Countries with Large-Scale Asset Purchases

Central banks in Japan and the United Kingdom also have engaged in large-scale purchases of longer-term assets to provide greater monetary stimulus at times when the conventional monetary policy

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[45]Using a longer sample and somewhat different specification, Greenwood and Vayanos (2010) also find a statistically significant effect of bond supply on the bond yields. They regress the spread of the five-year Treasury yield to the one-year Treasury yield and the spread of the twenty-year yield to the one-year yield on the ratio of Treasury securities with maturities greater than ten years to total Treasury securities. They do not subtract SOMA or TIC holdings. Over the period 1952–2005, they find that a 1-percentage-point increase in the share of Treasury securities with maturities above ten years increases the five-year yield spread 4 basis points and the twenty-year yield spread 8 basis points.

[46]The event-study range is somewhat higher than the time-series range. This difference may reflect that LSAP effects are larger when financial conditions are strained. Alternatively, it is possible that the effect of maturity supply on bond yields is non-linear, so that large reductions in net supply have a proportionally larger (or smaller) effect on yields. The LSAP programs constituted a large shift in maturity supply by historical standards.

Table 4. OLS Regression of Ten-Year Treasury Yield, December 1986–June 2008

	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
Constant	0.297	0.432	0.103	0.443	−0.013	0.513
Rate Expectations						
Target Federal Funds	0.403***	0.114	0.424***	0.118	0.742***	0.114
Eurodollar Slope	0.477*	0.214	0.478*	0.225	0.602*	0.273
Cyclical Factors						
Unemployment Gap	0.127	0.208	0.172	0.210	0.784***	0.198
Core CPI	0.378**	0.125	0.342**	0.131	0.163	0.157
Uncertainty						
Inflation Disagreement	0.210	0.165	0.215	0.170	0.111	0.187
Realized Volatility	1.057***	0.25	1.145***	0.27	1.340***	0.31
Supply						
Unadjusted	0.069***	0.014	—	—	—	—
Duration-Adjusted	—	—	0.098***	0.023	—	—
Adjusted R-squared	0.92		0.91		0.88	
Standard Error of Regression	0.45		0.46		0.53	
Number of Observations	259		259		259	

Notes: Newey West standard errors (twelve lags). ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Table 5. Effect of 1-Percent-of-GDP Increase in Long-Term Debt and Total Effect of LSAPs on Ten-Year Term Premium (bps)

	OLS Term Premium Model	DOLS Term Premium Model[a]	Yield Level Model
Effect of 1-Percent-of-GDP Increase in Long-Term Debt on Ten-Year Premium (bps)			
Unadjusted	4.4	4.2	6.9
Duration-Adjusted	6.4	6.2	9.8
Total Effect of LSAPs on Ten-Year Term Premium (bps)			
Unadjusted	52	50	82
[95% CI]	[31 to 74]	[31 to 69]	[50 to 115]
Duration-Adjusted	38	36	58
[95% CI]	[22 to 54]	[20 to 53]	[31 to 84]

[a]Long-run effect.

interest rate was close to zero.[47] The effects on longer-term yields in Japan appear to have been small, reflecting the smaller scale of the purchases and the shorter maturities purchased. In the United Kingdom, where the purchases were of a similar scale and maturity to those in the United States, the effects on longer-term yields have been similar to those in the United States.

5.1   Japan, 2001–06

In March 2001, the Bank of Japan (BOJ) introduced the quantitative easing policy (QEP) to fight deflation. The main element of the QEP was to supply banks with more than sufficient liquidity to keep the overnight interest rate at zero and thus to encourage bank lending. A secondary element of the QEP was a commitment to maintain zero interest rates until the core consumer price inflation rate was sustainably above zero. Purchases of Japanese government bonds (JGBs) were a tertiary element of QEP, but the BOJ did not claim that purchases of JGBs would reduce longer-term interest rates. Rather, JGBs were viewed as an appropriate and convenient asset for the BOJ to buy in order to supply banks with liquidity.

Ugai (2007) reports that studies of the portfolio balance effect of JGB purchases under the QEP find either small or insignificant effects on longer-term interest rates, including on corporate bonds. Bernanke, Reinhart, and Sack (2004) also report only a small effect of news about JGB purchases on longer-term yields. Relatively small effects on yields probably reflect that the JGB purchases were not large as a share of GDP and that they were skewed toward bonds with short residual maturities. According to Ugai (2007), the peak increase in BOJ holdings of JGBs under the QEP was about 4 percent of GDP, considerably less than the 12 percent of GDP increase in Federal Reserve holdings under the LSAPs. McCauley and Ueda

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[47]In May 2009, the European Central Bank (ECB) announced plans to purchase €60 billion of covered bonds, which have a range of maturities. Relative to euro-area GDP, this program is about one-twentieth the size of the U.S. and U.K. asset purchase programs, and its effects on longer-term interest rates are likely to be very small. In May 2010, the ECB announced plans to purchase sovereign bonds of its member countries in order to improve market depth and liquidity. The program was not aimed at lowering interest rates in general, and planned purchase amounts have not been announced.

(2009) show that the additional BOJ purchases were mainly seasoned JGBs with short residual maturities; the average maturity of the BOJ's holdings of JGBs fell from more than five years to less than four years under the QEP.[48] Moreover, the Ministry of Finance increased the average maturity of newly issued JGBs from five years in 2001 to six and a half years in 2005, further offsetting any effect of the QEP on longer-term bond yields.

5.2   United Kingdom, 2009–10

On February 11, 2009, Governor King of the Bank of England (BOE) stated at a press conference that "further easing in monetary policy may well be required." At that time the BOE's policy interest rate target was 1 percent. When asked about the scope for further easing so close to the zero lower bound, King said "we will be moving to a world in which we will be buying a range of assets, but certainly including gilts."[49] On March 5, the BOE lowered its policy rate target to 0.5 percent and announced plans to purchase £75 billion in assets, mainly gilts with residual maturities between five and twenty-five years. In contrast to the Federal Reserve's LSAP programs, which were adjusted only once, the BOE adopted a more active approach to adjusting its asset purchase program. On May 7 the program was expanded to £125 billion. On August 6 it was expanded to £175 billion. On November 5 it was expanded to £200 billion. On February 4, 2010, after the £200 billion target was reached, the BOE said it would cease additional purchases but would continue to monitor the appropriate scale of the program in light of the economic outlook.

The BOE gilt purchases, at 14 percent of U.K. GDP, were similar in scale to the Federal Reserve LSAPs, at 12 percent of U.S. GDP. According to table B in Joyce et al. (2010), the average yield on five- to twenty-five-year gilts fell 100 basis points in total during two-day windows surrounding the six announcement dates noted above. That

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[48]Total BOJ holdings of JGBs increased about 45 percent from 2001 to 2005. If redemptions on the initial holdings are assumed to be replaced with JGBs of sufficient maturity to hold the average maturity of those holdings constant, then the additional JGB purchases under the QEP would have had an average maturity of less than one year.

[49]Joyce et al. (2010, p. 12).

decline is strikingly similar to the 106-basis-point decline in U.S. ten-year Treasury yields (using two-day windows around the baseline event set) shown in figure 7 of this paper. In both the U.K. and U.S. event studies, yields on one-year and two-year bonds fell very little, suggesting that expectations about the future policy interest rate were not responsible for most of the decline in longer-term yields.

Over the six announcement dates, U.K. investment-grade corporate yields fell 70 basis points and U.K. speculative-grade corporate yields fell 150 basis points. These declines are broadly comparable to the declines on similar classes of corporate bonds in the United States around the U.S. event dates. One puzzling difference between the U.S. and U.K. experiences is that ten-year swap rates fell only 10 basis points in the U.K. event windows whereas they fell 100 basis points in the U.S. event windows.[50]

6.   Conclusion

With policy interest rates in many countries constrained by the zero bound, and with short-term interest rates in Japan having been near zero for over a decade, expanding the toolkit of monetary policy is an important objective. In this paper, we examined lessons from the experience of the Federal Reserve since late 2008 with one of the key policy tools available at the zero bound—large-scale purchases of longer-term assets.

By reducing the net supply of assets with long duration, the Federal Reserve's LSAP programs appear to have succeeded in reducing the term premium. The overall size of the reduction in the ten-year term premium appears to be somewhere between 30 and 100 basis points, with most estimates in the lower and middle thirds of this range. In addition to this reduction in the term premium, the LSAP programs had an even more powerful effect on longer-term interest rates on agency debt and agency MBS by improving market liquidity

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[50]The U.K. swap rates in Joyce et al. (2010) are linked to the sterling overnight index average (SONIA) rate whereas the U.S. swap rates in this paper are linked to the three-month LIBOR. U.S. ten-year swap rates based on the overnight federal funds rate fell 50 basis points in two-day windows around our baseline event dates.

and by removing assets with high prepayment risk from private port-folios. Similar effects appear to have occurred in the United Kingdom after the Bank of England launched a broadly similar LSAP program in 2009.

Based on this evidence, we conclude that the Federal Reserve's LSAP programs did lower longer-term private borrowing rates, which should stimulate economic activity. While the effects are espe-cially noticeable in the mortgage market, they appear to be wide-spread, including in the markets for Treasury securities, corporate bonds, and interest rate swaps. That conclusion is promising, as it means that monetary policy remains potent even after the zero bound is reached. To be sure, achieving this further stimulus was not without its challenges, as it required a sizable expansion of the Federal Reserve's balance sheet, and the purchase of such a large volume of securities in a relatively short time frame required sur-mounting some operational hurdles. However, by restoring function-ing to the mortgage market and lowering the term premium, the programs provided considerable benefits.

Even though the LSAPs appear to have been successful, it is worth reflecting on their structure and considering whether the approach taken was optimal. The LSAPs, as implemented, were dis-crete in nature, in that the broad characteristics of the programs were set in two decisions upfront (in November 2008 and March 2009). The remainder of the programs involved carrying out those decisions, with little responsiveness to changes in the economic or financial outlook.

By stating a specific amount and a timetable for LSAPs upfront, the FOMC appeared to commit itself to a future course of action. This commitment was softened somewhat by the use of the phrase "up to" before the specified purchase amounts. However, market participants generally indicated that they expected the full amounts to be purchased, and in the later stages of the programs the FOMC made it clear that close to the full amounts would be purchased. Pol-icymakers often prefer not to make strong commitments on future policies because there is always a chance that future economic condi-tions will call for a different policy stance than expected. Policymak-ers may want to assess the benefits of this element of commitment relative to an approach that instead allows greater responsiveness to economic and financial conditions. Bullard (2009) lays out the

theoretical case for a policy rule for LSAPs analogous to conventional policy rules for interest rates, but he shows that the practical issues in designing such a rule are substantial, particularly in light of the limited historical experience of economies operating near the zero bound on nominal interest rates.[51] Clearly, study of both the theoretical and empirical issues raised by LSAPs would be helpful in order to assess whether they can be employed even more effectively in the future.

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[51]An alternative strategy, proposed by Bernanke (2002), is to use unlimited purchases to target near-zero yields on Treasury securities with successively longer maturities, starting with one-year securities. This strategy entails a completely elastic response of LSAPs to interest rates on the targeted securities but leaves open the question of how to relate the choice of targeted maturities to economic conditions.

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