

The Federal Reserve's Large-Scale Asset Purchases (LSAPs), Mortgage-Backed Securities (MBS) Yields and U.S. Mortgage Rates

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Abstract

We provide an empirical analysis of the effects of Federal Reserve large-scale asset purchases (LSAPs) on MBS yields and mortgage rates during periods when financial markets are not in turmoil. We investigate the magnitudes of the effects from the accumulation of MBS and Treasury securities by the Federal Reserve on MBS yields, and find that this accumulation has significantly lowered MBS yields. Our estimates also suggest that the Federal Reserve must hold a substantial market share of agency MBS or of Treasury securities to significantly lower MBS yields and in turn significantly lower mortgage rates. We find evidence that the agency MBS market does not fully anticipate the effects of LSAPs on MBS yields (that is, market participants have been surprised by FOMC announcements). Moreover, market participants appear to underestimate the potential effect of Federal Reserve asset purchase programs on MBS yields. Finally, we also find that both MBS-based and Treasury securities-based LSAPs have lowered the compensation for the risks associated with holding agency MBS.

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1. An Introduction to Quantitative Easing (QE)

Even before the recent financial crises, central bankers argued that monetary policy could retain its potency even when short-term rates are zero because central banks could also use open market operations, that is, purchases of a wide variety of assets, not just short-term government securities (King, 1999; Bernanke, 2002). Such operations, for example, could be used to enforce explicit ceilings for yields on longer-term securities, including longer-dated Treasury securities, agency debt, or agency mortgage-backed securities (Bernanke, 2002).² If such a long-term asset purchase program were successful, not only would yields on such securities fall, but yields on private debt (such as mortgages) would likely fall as well. Moreover, with an increase in the monetary base, asset prices in general could rise and have an impact on spending (Mishkin, 1996; King, 1999). For these and other reasons, it was posited that even a central bank whose accustomed policy rate has been forced down to zero would not “run out of ammunition” (Bernanke, 2002).

In this study, we consider the effects of Federal Reserve large-scale purchases of long-term assets, commonly known as “quantitative easing” (QE) programs, on agency mortgage-backed securities (MBS) yields (and thereby on U.S. conforming mortgage rates). We focus on periods when financial markets are functioning fairly well, rather than when MBS markets were in turmoil.³ During normal economic times, the prevailing view in the economics literature is that an LSAP should have no effects on asset prices.⁴ Others, however, have argued that the Federal Reserve’s large-scale asset purchase (LSAP) programs can potentially work through three transmission channels: (1) portfolio rebalancing effects, (2) liquidity effects, and (3) signaling Federal Reserve intentions to financial markets. All components of MBS yields are likely influenced somewhat through these channels.

² Bond-price pegging for long-term bond yields was successfully implemented by the Federal Reserve during the years prior to the Federal Reserve-Treasury Accord of 1951 (Bernanke, 2002; D’Amico, English, Lopez-Salido, and Nelson, 2012).

³ See Hancock and Passmore (2011) for estimates of how Federal Reserve MBS purchases during November 2008 through March 2010 provided a clearer government backing for Fannie Mae and Freddie Mac and also improved market functioning in both primary and secondary mortgage markets. These transmission channels are not the focus of this study, which focuses on the periods when the markets are functioning fairly well.

⁴ See Narayana Kocherlakota’s (2012) discussion of quantitative easing, based on Wallace (1981) and Eggertsson and Woodward (2003).

Large-scale asset purchases (LSAPs) by the Federal Reserve can potentially affect MBS yields (and other asset prices) through a portfolio rebalancing transmission channel that works as follows: (1) the Federal Reserve purchases an asset and reduces the amount of the security that the private sector holds, while simultaneously increasing the amount of short-term, risk-free, bank deposits held by the private sector, (2) private sector investors hold more deposits than they desire because of the payments received to purchase their Treasury and agency securities, (3) the private sector investors desire to reduce their holdings of deposits and bid up the prices of the remaining longer-term securities and, as a result, there are lower yields on such securities.⁵

For longer-term securities, this portfolio rebalancing argument is often told in terms of duration and convexity risk: If the Federal Reserve withdraws MBS from the market, the institutions in the private sector that take these risks find themselves with too much cash on hand and cannot meet their demands for duration and convexity without bidding more aggressively for MBS. The potential portfolio rebalancing adjustments made by these investors have two components: (1) a willingness to take less compensation for hedging the interest rate risks of financial assets, or a “duration effect,” that applies to both Treasury securities and MBS; and (2) a willingness to take less compensation for hedging the prepayment and volatility risks that are associated with holding MBS or a “convexity effect.”⁶ When purchasing Treasury securities, the Federal Reserve was quite aware of the duration effect and specifically targeted its purchases of Treasury securities toward those with a maturity of 4 to 7 years, so that it would withdraw more duration from the market.⁷ MBS typically have a duration that is in the 4 to 7 year range.

⁵ One concern is that low interest rates and portfolio purchases might lead to a “search-for-yield” by investors, which when combined with mortgage securitization, might induce both lax underwriting standards by lenders and a diminishment of due diligence by investors. Such a scenario was an instrumental part of the recent financial crisis (see, for example, Maddaloni and Peydro (2011)). During the post-crisis period, however, virtually all mortgage securitization in the United States has been funneled through Fannie Mae, Freddie Mac or Ginnie Mae, and the general concern has been that underwriting standards by these entities, as well as by the originating lenders, have been too tight relative to the potential credit risks (Bernanke, 2012).

⁶ These types of portfolio readjustments are described in Tobin (1958), Bernanke and Reinhart (2004), and Gagnon, et al. (2010). With respect to the effects of the Federal Reserve’s MBS program, Fuster and Willen (2010), Hancock and Passmore (2011), Krishnamurthy and Vissing-Jorgensen (2011), Stroebel and Taylor (2010), and Gagnon, et al. (2010) each use different empirical techniques to provide evidence of substantial announcement effects for the program in November 2009, but differ with respect to the magnitude of the effects afterwards.

⁷ See “Sizing Up the Maturity Extension Program,” blog post on the Federal Reserve Bank of New York’s Liberty Street Economics web site by Katherine Femia, Jeff Hunter and Andrea Tambalotti, October 19, 2011.

At the same time, LSAPs by the Federal Reserve could potentially operate through a liquidity channel. Liquidity can mean different things for different types of assets: here we outline two possibilities. First, liquidity may be defined as the ease of reselling assets in the future.⁸ This definition is in line with Acharya and Pedersen (2005), who propose that liquidity is defined by how the security performs in a “bad” market.⁹ Investors are willing to pay a premium for a security that remains easy to sell when most other securities become illiquid or when market returns overall are low. How Federal Reserve asset purchases affect liquidity is unclear. On the one hand, the Federal Reserve’s LSAPs may increase the ability of investors to sell their securities in the future, particularly during “bad” markets, because market participants believe the Federal Reserve will be a large and persistent buyer during any “bad” market. On the other hand, as the Federal Reserve’s holdings of a security increases during “normal” times, the private sector holdings of the security may diminish, leading to a thinner market in the future with fewer opportunities to sell the security to other private market participants. Withdrawal of securities from the private sector by the Federal Reserve might diminish expected future liquidity if private market participants are uncertain about whether or not the Federal Reserve (or some other government entity) will be buying in a “bad” market in the future.

The Federal Reserve is concerned about “too much” disruption in the MBS market. Indeed, the Federal Reserve activity participates in the “dollar roll” market for MBS to mitigate the effects of day-to-day short-term flow disruptions. Longer-term flow and stock shortages, however, are the essence of the liquidity and portfolio rebalancing channels. Market participants must find the desired holdings of securities more costly to obtain. We will be measuring the potential shortage of MBS using the Federal Reserve’s market share of 30-year fixed-rate agency MBS.

Another form of liquidity is the accumulation of reserves in the banking system.¹⁰ This is

⁸ Kiyotaki and Moore (2012) analyze this form of liquidity.

⁹ This “safety premium” is also documented by Krishnamurthy and Vissing-Jorgensen (2011).

¹⁰ Liquidity portfolios at banks in particular may be affected by liquidity effects. Banks maintain substantial liquidity portfolios of Treasury securities and agency MBS, which may be less needed as excess reserves accumulate in the banking system. How banks react to the accumulation of reserves depends on the marginal costs associated with balance sheet expansion. If the marginal costs of adding deposits and reserves are low because bank capital is cheap and readily available, these reserves should have little effect on a bank’s willingness to hold Treasury securities and agency MBS securities (Martin, A., J. McAndrews and D. Skeie, 2011; Carpenter and Demiralp, 2010). But if bank capital is dear, then balance sheet expansion may be costly. Overall, the effect of adding reserves into the banking system (and symmetrically adding additional deposits to investor portfolios) on MBS yields becomes an empirical

the “flip side” of the portfolio rebalancing channel described earlier. The portfolio rebalancing channel described the desire of market participants to rebalance a risk-adjusted portfolio. But the injection of deposits and reserves may also simply reduce the need for liquidity overall. As noted by Krishnamurthy and Vissing-Jorgensen (2011), this traditional source of liquidity arises because bank deposits and excess reserves (deposits at the central bank) are even more liquid than Treasury securities and MBS. Thus, additional deposits may cheapen the liquidity value of assets like longer-term Treasury securities and agency MBS for banks. On the one hand, if investors desire a given amount of liquidity and want a fixed proportion of bank deposits, Treasury securities, and agency MBS in their liquidly portfolio, then increasing bank deposits in the hands of these investors would cause them to rebalance and perhaps bid more aggressively for a small pool of Treasury securities and agency MBS (the portfolio rebalancing channel). But on the other hand, if the size of desired liquidity portfolios decline because the system is awash in bank deposits, then the desire by private investors to hold Treasury securities and agency MBS may also decline, perhaps leading to the selling of Treasury securities and agency MBS, which results in relatively higher MBS yields.

Finally, the most general effect of Federal Reserve LSAPs is derived from the signals provided by the FOMC that are sent to, and received by, all market participants. The signaling transmission channel operates principally via an impact on the expectations component of longer-term rates. Long-term asset purchases may increase the credibility of the Federal Reserve’s commitment to keep interest rates lower than what the application of a Taylor rule would imply even after the economy recovers, particularly if the central bank weighs potential losses on its asset holdings in its objective function (Bauer and Rudebusch, 2012; Krishnamurthy and Vissing-Jorgensen, 2011, Eggertson and Woodford, 2003; Clouse, Henderson, Orphanides, Small and Tinsley, 2000). This channel affects all bond market interest rates, since lower future federal funds rates can be expected to affect all interest rates. Note, if market participants anticipate the announcement of Federal Reserve LSAPs, the effects of asset purchase programs can be reflected in market prices even before they are announced.

question.

2. A Review of Federal Reserve Actions

Table 1 updates the compilation of dates and announcements pertaining to monetary policy accommodation at the interest-rate lower bound that was developed by Woodford (2012).¹¹ In addition, table 1 delineates the timing of the announcements for three separate rounds of QE—denoted using QE1, QE2, and QE3 in the fourth column—as well as when asset sales and purchases were taken to lengthen the maturities and to change the composition of the Federal Reserve’s balance sheet—transactions that are sometimes described as an “Operation Twist,” which is denoted by OT. The rightmost column of table 1 indicates whether each announcement is about an increase or a decrease in LSAPs, denoted by “increase” or “decrease,” respectively; or is about the rationale for, or readiness of the Federal Reserve to engage in, accommodative monetary policy actions, described as a communication about asset purchases and denoted by “Com.”

QE1 began in November 2008 when the Federal Reserve announced that it would initiate a program to purchase substantial quantities of MBS backed by Ginnie Mae, of agency debt, and of MBS backed by the housing-related government-sponsored enterprises (i.e., Fannie Mae and Freddie Mac) and ended in March 31, 2010 when the previously announced asset purchases had been completed.^{12, 13} In contrast, QE2 involved purchases of Treasury securities: In August 2010, the Federal Reserve announced that it would redeploy into longer-term Treasury investments the principal payments from agency securities and in November 2010 it indicated that it would purchase an additional \$600 billion of longer-term Treasury securities by the end of the second-quarter of 2011. This second round of QE, the purpose of which was to end the *de facto* tightening

¹¹ A similar exercise was conducted by Fawley and Neely (2013) for quantitative easing programs of the Bank of England, European Central Bank, and Bank of Japan during the recent financial crisis and recovery.

¹² Bernanke (2009) argues that this type of central bank actions is different from quantitative easing because the assets of the central bank are being altered with a goal of influencing the credit risks and decisions of economic actors, and not with the goal of adding excess reserves holdings of the banking system. He refers to these types of actions as credit easing rather than quantitative easing. While we agree with this perspective, we bend to the popular nomenclature and refer to the Federal Reserve’s long-term asset purchase programs as quantitative easing.

¹³ On March 16, 2010, the Federal Open Market Committee issued a press release stating: "To provide support to mortgage lending and housing markets and to improve overall conditions in private credit markets, the Federal Reserve has been purchasing \$1.25 trillion of agency mortgage-backed securities and about \$175 billion of agency debt; those purchases are nearing completion, and the remaining transactions will be executed by the end of this month."

of credit that occurred as the Federal Reserve portfolio shrank, ended on June 20, 2011.¹⁴

Operation twist, OT, began in September 2011 when the Federal Reserve initiated further adjustments to its portfolio, including an extension of the average maturity of its Treasury securities holdings and reinvestments of principal payments from agency securities into MBS, rather than into longer-term Treasury securities.

And on September 13, 2012, the third round of quantitative easing, QE3, began when the Federal Reserve announced that it would (1) increase policy accommodation by purchasing additional agency MBS at a pace of \$40 billion per month,¹⁵ (2) continue through the end of 2012 its program to extend the average maturity of its holdings of securities, (3) and maintain its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities. These actions, which together increased the holdings of longer-term securities by about \$85 billion each month at least through the end of 2012, were taken to “put downward pressure on longer-term interest rates, support mortgage markets, and help to make broader financial conditions more accommodative.”¹⁶

The sixteen announcements made since 2008 and the long-term asset purchases that have been undertaken, some of which were more targeted towards mortgage markets than others, changed both the size and the composition of the Federal Reserve balance sheet during 2009-2012. The Federal Reserve’s purchases of Treasury securities (the solid black line) and agency MBS (the dotted black line) are shown in the top panel of figure 1. Note that during QE2 (indicated by shading), MBS purchases were allowed to runoff and were replaced with longer-term Treasury securities. Thus, there are no MBS purchases during this period. As shown by the black line in the top panel of figure 1, Federal Reserve MBS purchases were greatest during QE1.

In the middle panel of figure 1, the cumulative stock of Treasury bond holdings (the solid

¹⁴ On June 22, 2011, the Federal Open Market Committee issued a statement stating: "The Committee will complete its purchases of \$600 billion of longer-term Treasury securities by the end of this month and will maintain its existing policy of reinvesting principal payments from its securities holdings."

¹⁵ The purchases were expected to continue as long as the labor market did not improve substantially. The Committee generally articulated a view to keep monetary policy accommodative even if asset purchases were ended, so long as unemployment remained above 6.5 percent and inflation between one and two years ahead was expected not to exceed 2.5 percent. See the Federal Open Market Committee press releases, dated September 13, 2012.

¹⁶ See the Federal Open Market Committee press release that is dated October 24, 2012.

black line) and Federal Reserve agency MBS holdings (shown by the dotted line) eventually amounted to about one-fifth of all outstanding Treasury securities and fixed-rate agency MBS.¹⁷ Note, however, that since late 2011, the Federal Reserve's market shares of these securities have declined slightly. In addition, these purchases resulted in the accumulation of reserves within the banking system (bottom panel.) Roughly 12 percent of banks' assets were held in excess reserves at year-end 2012.¹⁸

3. MBS Yields and LSAPs

Accommodative monetary policy actions have resulted in the Federal Reserve holding substantial market shares of securities in the Treasury security market and the MBS market. These market shares potentially could result in (1) portfolio rebalancing and changes in market liquidity, (2) increased amounts of excess reserves held by the banking system, which could affect liquidity, and (3) altered expectations about future interest rates through signaling of Federal Reserve actions, including LSAPs. To preview our findings, our estimates suggest that the Federal Reserve's purchases and its resultant portfolio holdings influence mortgage markets. Moreover, the empirical evidence suggests that substantial security purchases are required to significantly lower MBS yields and mortgage rates.

As a hypothetical example, the purchase of \$50 billion of MBS securities per month over the course of six months, holding the Federal Reserve's share of Treasury securities constant, lowers MBS yields by about 100 basis points, all else equal. In response to the decline in MBS yields, mortgage rates decline by about 81 basis points. A similar hypothetical example based on the same-sized purchases of long-term Treasury securities (holding the Federal Reserve's share of MBS purchases constant) yields a decline in MBS yields of 88 basis points and a decline in mortgage rates of 72 basis points. These portfolio rebalancing effects that lower MBS yields are amplified through the anticipation of additional quantitative easing. More specifically, the signaling effect is large when a program is announced (about 41 basis points on net), but this effect diminishes as the portfolio rebalancing effect kicks-in (i.e., as actual securities holdings increase as

¹⁷ The stock of outstanding MBS excludes MBS held in the portfolios of Fannie Mae and Freddie Mac.

¹⁸ All Federal Reserve purchases eventually become excess reserves holdings at domestic banks, cash holdings by foreign entities, or unspent cash held by households. Specifically, we consider the banks' reserve balances held at the Federal Reserve (weekly data reported in the H.4.1 statistical release) divided by the total assets at all commercial banks, domestic and foreign (weekly data reported in the H.8 release).

a result of Federal Reserve purchases). That said, the signaling effect becomes larger if economic underperformance persists and market participants come to expect additional quantitative easing (i.e., additional large-scale asset purchases).

Finally, an MBS purchase program along the lines described in the hypothetical example also lowers the compensation for the risks of holding MBS by about 10 basis points. Thus, MBS and Treasury security purchases lower not only the level of MBS yields, but also seem to lower the risk compensation received by investors for holding agency MBS. This reduction in risk compensation is consistent with the portfolio rebalancing channel described above.

Our study is unique in that we focus on MBS yields, rather than on Treasury security yields (as do D'Amico, English, Lopez-Salido, and Nelson, 2012) or on across assets more broadly (as do Krishnamurthy and Vissing-Jorgensen, 2011). To date, most other researchers have focused on event studies of Federal Reserve longer-term asset purchase programs (e.g., Gagnon et al., 2010 and Wright, 2011).¹⁹ Event studies attempt to isolate the effects of an accommodative policy by defining a brief period during which market participants become informed about a Federal Reserve policy action and respond to it. For event studies, it is assumed that market participants have expectations about the future consequences of the accommodative policy action and that these consequences are quickly reflected in the prices for financial assets. In contrast, our approach assumes that information about the effects of new quantitative easing programs, or about long-term asset purchases, is often learned over time; consequently asset prices adjust more slowly.²⁰ Moreover, the liquidity effects associated with asset purchase programs, which are created as securities are withdrawn from the private market, are difficult to understand, or to predict, when asset purchase programs are announced.

We consider the MBS market because it is likely to have investors with a strong preferred habitat because of the considerable expertise that is needed to manage interest rate and prepayment

¹⁹ A notable exceptions are D'Amico and King (2010) and D'Amico, English, Lopez-Salido, and Nelson (2012), who focus on the effects of Federal Reserve Treasury purchases on Treasury yields by looking at particular Treasury securities.

²⁰ The exception was the Federal Reserve's announcement of MBS purchase program on November, 2009. This surprise announcement had an immediate effect because it provided a strong statement of government support for financial markets during a time of financial instability. All techniques used to measure the effects of the Federal Reserve's purchase programs registered an immediate and dramatic reduction in interest rates as a result of this announcement.

risks (thus perhaps making it a better candidate for portfolio rebalancing adjustments) and also because one of the goals of the Federal Reserve's large-scale (longer-term) asset purchase programs, as indicated above, was to support mortgage markets. As suggested in figure 2, both agency MBS yields and fixed-rate mortgage rates were pushed down by QE1 and have subsequently remained relatively low compared to levels that were observed prior to the financial crisis.²¹ Here, we examine how effective Federal Reserve LSAPs have been *after* QE1. Our foregoing discussion on the potential transmission channels for the effects of LSAPs on MBS yields suggests that an MBS yield regression can be decomposed into four factors: (1) the effects of withdrawing supply from securities markets, resulting both from liquidity effects and portfolio rebalancing, (2) effects on market participant expectations from Federal Reserve announcements about longer-term asset purchases ("signaling effects"), and (3) other factors, such as higher risk premiums because of the European crisis.

Measuring Liquidity and Portfolio Rebalancing Effects

From the discussion of the liquidity channel and portfolio rebalancing channels above, a higher share of Federal Reserve security ownership could result in MBS yields either rising, falling, or remaining unchanged. To estimate the net result of these different channels, we use the Federal Reserve's share of MBS outstanding divided by total agency MBS outstanding that is backed by 30-year fixed rate mortgages (dotted line, middle panel, figure 1).²² We create a similar market share measure for the Federal Reserve's share of Treasury bonds and notes outstanding (solid line). These measures capture the idea that the Federal Reserve is withdrawing securities from the private sector.

Measuring Signaling Effects

Investors, of course, anticipate both the announcements and the effects of LSAP programs. Indeed, this is the premise of the many papers that have used event studies to capture MBS effects. We attempt to capture investor anticipations by combining traditional announcement effects, which bring forward the expected effects of a QE program on future interest rates, with a novel measure

²¹ We described this process in Hancock and Passmore (2011). A basic description of the U.S. mortgage market and current issues regarding mortgage policies can be found in Hoskins, Jones and Weiss (2013).

²² We exclude Fannie Mae's and Freddie Mac's MBS portfolio holdings.

that encapsulates market participants' anticipation of future FOMC actions. Together, the traditional and anticipation effects account for the signaling channel discussed above.

For traditional announcement effects, we classify FOMC announcements into three categories: (1) announcements about increasing either Treasury or MBS purchases, (2) communications about the continuation of a purchase program or about possibly increasing a purchase program, and (3) announcements that result in a decrease in monthly Treasury or MBS purchases (there are only two such announcements). We incorporate traditional announcement effects using announcement indicators that equal one on announcement dates in either category (1) or (2), and zero otherwise.

We incorporate market participants' anticipation of FOMC announcements by including a "probability of announcement" effect. The FOMC is concerned about inflation and unemployment and, at the zero lower-bound for the federal funds rate; it uses LSAPs to put downward pressure on longer-term interest rates when data indicate that the economy is performing at a "sub-par" level. By pushing down interest rates, the FOMC hopes to generate more employment, while maintaining inflation slightly above zero.

Using daily data from a pre-crisis period, April 2, 2001 through December 29, 2006, inclusive, we estimate a simple (forecasting) model of the ten-year Treasury rate as a function of the *lagged four-week moving average* of inflation expectations (as measured by the inflation compensation embedded in the ten-year Treasury rate) and of the *lagged twelve-week moving average* of the unemployment rate. We emphasize the lagged structure of the right-hand side variables because this structure is employed to minimize the endogenous effects of FOMC actions on our probability of action measure. The OLS regression results are provided in the upper left panel of figure 3. We interpret this 10-year Treasury rate model as the "normal" relationship between the long-term interest rate, inflation and unemployment before the persistent financial and economic stresses observed during and after 2008.

The out-of-sample residual from this ten-year Treasury specification is used as a summary measure of how much the economy and the financial system are deviating away from "normal" (i.e., the relationship observed prior to the crisis). When the observed ten-year Treasury rate is lower than the estimated "normal" rate observed pre-crisis, the residual indicates how much ten-year Treasury yields are below their expected level (i.e., the level that is consistent with fuller

employment and/or higher expected inflation) as shown in the lower left panel of figure 3. We assume that market participants think that an FOMC announcement of an LSAP is more likely the more negative the out-of-sample Treasury residual. In turn, the more likely an FOMC announcement, the more downward pressure is exerted on MBS yields in anticipation of an announcement. Of course, since this measure is also a measure of economy's performance, the higher probability of action may also be a signal of a poor economy, which in itself might lower the MBS yield as investor seek a credit-guaranteed financial instrument.

We estimate the effects of market participants' anticipation of the probability of an FOMC LSAP announcement using a probit model. More specifically, we use a *lagged four-week moving average* of the residual from the Treasury regression described above, which turns out to be a fairly good predictor of the likelihood the FOMC will announce an LSAP. Investors might perceive that the bigger the (negative) residual from the out-of-sample pre-crisis estimates of the ten-year Treasury yield, the more likely an LSAP will be announced. We interact the days since the last announcement as an exogenous variable (figure 4, upper right panel) in a probit equation. The longer the "days since the last announcement" variable and the more negative the out-of-sample Treasury residual, which indicates the economy is underperforming, then the greater the market's anticipation of another LSAP purchase announcement. The coefficient, shown in line 2, is significantly negative.

We also include in the probit specification the spread on credit default swaps (CDS) on European sovereign debt in financially troubled European countries. This CDS spread, which is somewhat exogenous to U.S. financial markets, might move the odds of a FOMC announcement either up or down, depending on the likelihood of a negative impact on the United States economy. The estimated coefficient on European sovereign CDS spreads is significantly negative, suggesting that financial stress in Europe makes an FOMC LSAP announcement less likely. The sign of this coefficient is consistent with ten-year Treasury yields being driven lower because of "a flight to quality" from Europe thereby reducing the likelihood of an LSAP announcement.

Below, when measuring signaling effects, we include both the announcement fixed effect and this probability of announcement variable in our specification for MBS yields. Like event studies, the announcement fixed effect captures when market participants are surprised by an LSAP announcement. By adding the probability of an announcement variable, we add to the

announcement fixed effect an estimate of market participants' anticipation of an LSAP announcement. One can think of this as the decline in yields that occurs because market participants expect that an LSAP is on the horizon.

Since expectation of a LSAP program's effects and the elimination of the anticipation of the LSAP's announcement are one and the same on the date of announcement, we avoid overlapping the announcement indicator and anticipation of an announcement variable when we estimate signaling effects. That is, the anticipation effect (equal to the probability of another LSAP) is "zeroed out" when the announcement fixed effect (equal to one on the day of the announcement) is "turned on."

Regression Estimates

We estimate the effects of the Federal Reserve's LSAPs using the "current-coupon" MBS yield as the dependent variable.²³ The coefficients and t-statistics for the MBS yield regression, which is estimated using weekly data over May 27, 2009 to December 26, 2012, is presented in figure 4.²⁴ The regression includes the market shares of Federal Reserve securities holdings and the measures of announcement and anticipation of announcement effects described above, as well as a measure of continued market turbulence after 2008: the CDS spreads for sovereign debt of European countries (Italy, Ireland, Spain and Portugal).

Note that the Federal Reserve MBS market share is I(1), as is the MBS yield. It is perhaps unusual for a market interest rate to be I(1), but the MBS yield is codetermined with the Federal Reserve's holdings and that codetermination is what we are describing with the regression. We include the European debt crisis as another possible co-determining variable; it also is I(1).

An increase in either the Federal Reserve market share of MBS (line 2), or its market share of US Treasury securities (line 3), significantly lowered MBS yields during the sample period at the 5 percent level of confidence. Using the estimate in line 2, the MBS yield is about 151 basis

²³ The MBS yield estimates are typically based on an interpolation of the MBS yield curve that uses coupons observed in the "to be announced" (TBA) market for MBS. The so-called "current coupon" may not actually exist in the market.

²⁴ Because of the confusions among MBS market participants during QE1 concerning Federal Reserve objectives and the mortgage rate, we begin our QE1 period used for this regression on June 1, 2009. These confusions are discussed at length in (Hancock and Passmore, 2011).

points lower if the Federal Reserve holds 20 percent of the available MBS securities (at the end of 2012, this was about \$927 billion). The same estimate suggests that a \$50 billion increase in the Federal Reserve's MBS holdings would increase the mean market share of Federal Reserve MBS holdings (21.3 percent) to 22.4 percent and decrease MBS yields by 8.7 basis points.

An increase in Federal Reserve holdings of Treasury securities also lowered the MBS yield (line 3, figure 4). Using this estimate, the MBS yield is about 178 basis points lower if the Federal Reserve holds 20 percent of the available Treasury securities (at the end of 2012, this was about \$1.7 trillion). At the mean market share for the Federal Reserve's Treasury security holdings, a \$50 billion purchase of Treasury securities would lower the MBS yield by about 6.6 basis points.

Finally, the European economic and sovereign debt crisis, proxied using European sovereign CDS spreads, significantly lowered MBS yields (line 4). This negative coefficient might reflect a "flight to quality" effect, which may substantially influence swap yields (which are an important benchmark for agency MBS yields).

With regard to the signaling channel of monetary policy transmission, both the anticipation of announcement (line 5) and the actual announcement of an LSAP program (line 6) significantly lowered MBS yields. FOMC communications that announced either MBS or Treasury purchases initially lowered MBS yields about 135 basis points (line 6). However, offsetting this decrease is the elimination of the anticipation by the market of a program announcement. This elimination is captured when the probability of an announcement is reset to zero. The "net effect" of the initial announcement would be about 41 basis points. Thus, the market both anticipated and reacted to the Federal Reserve's announcements, and both signaling effects lowered MBS yields. However, the market reaction to the announcement was far greater than its reaction from the anticipation, suggesting that the market typically underestimates the size of the large-scale asset purchase programs. Moreover, if the market had fully anticipated the effects of the program going forward, the market share values should not have been significant determinates of the MBS yields. The statistically significant share coefficient estimates (lines 2 and 3) indicate that market participants underestimate the effects of the LSAPs on MBS yields.

4. An Illustration of the Magnitude of the Effects of Federal Reserve Purchases

To give a sense of the magnitudes of the various effects of Federal Reserve actions on MBS

yields and U.S. mortgage rates, we use the coefficient point estimates from the MBS yield regression to simulate the effect of a monthly purchase of \$50 billion of MBS by the Federal Reserve. We also repeat the simulation for same-sized monthly purchases of Treasury securities. In the MBS simulation, we assume that the Federal Reserve's ratio of Treasury bond holdings to the outstanding stock of Treasury securities is unchanged (and make the analogous assumption for the share of MBS holdings when performing the Treasury securities simulation).

Using the median values of the variables and the median for the number of days before an LSAP announcement (89 days), assuming that the size of the MBS market is unchanged, the effect of the foregoing hypothetical \$50 billion per month Federal Reserve MBS purchase program would result in an MBS yield that was 100 basis points lower after 6 months (figure 5, upper panel). Of course, this simulation is quite unrealistic because all other things are held equal. Since the share of Federal Reserve MBS holdings is a determinant of the level of the MBS yield, the pace of the flow of MBS purchases matters in determining how fast the MBS yield falls.

As shown by the vertical dashed line, the Federal Reserve usually amends its actions regarding LSAPs much sooner than 6 months after the announcement if the policy is perceived as inadequate to reestablishing a higher level of economic performance; the median time between all announcements was 89 days.

A purchase program consisting of Treasury securities is illustrated in the bottom panel of figure 5. It follows a similar pattern to that of the MBS purchase program, but results in an even lower MBS yield. Given the many assumptions behind this simulation, the larger effect should be taken with a grain of salt. However, it may reflect the more general effects of Treasury securities, particularly on the interest rate swap spread, which is a key determinate of MBS yields.

5. The Transmission of MBS Yields to Mortgage Rates

Ultimately, the goal of the Federal Reserve (in this context) is to lower mortgage rates. We argue that mortgage rates (r_m) can be modeled as a mark-up over the MBS yield (r_{MBS}). When banks and other providers originate a mortgage, they compare the marginal return from holding a mortgage to the marginal return that arises from holding an MBS. Note that the MBS yield already reflects the financing and hedging costs incurred by an investor when holding a mortgage asset. Similarly, the MBS yield already embeds the capital cost and the return on equity for bearing the

interest rate risk associated with the mortgage.

The bulk of the mark-up over MBS yields reflects an originator's credit risks and the capacity costs associated with refinancing mortgages should it decide to hold the mortgage. For example, higher FICO scores for homebuyers are expected to be associated with lower credit risks (as are many other such measures of credit risk). Our measure of credit risk is the FICO score of mortgage borrowers at the 75th percentile of the mortgage borrowers' FICO distribution; this measure is denoted by *FICO*.

The capacity of the mortgage system to process mortgage applications during a refinancing boom also plays a key role in mortgage rates. When refinancings are relatively high, banks and other mortgage originators raise their relative mortgage rates, as one method for managing their application "pipelines." Here, we measure the mortgage system's capacity as the ratio of mortgage refinancings (as measured by the MBS refinancing index) to the number of employees employed in the mortgage industry; this measure is denoted by *Capacity*.

Other factors that influence credit risks, such as inflation and home prices, are only captured in this model to the extent that they are components of the factors listed above. Of course, there are strong correlations with these two factors and other macroeconomic variables, but we keep the model parsimonious so the regression results can be more clearly interpreted.

Finally, the intercept in the mortgage rate regression would represent any persistence in the additional equity premium demanded by investors in the costs of managing credit risks (beyond the GSEs' pricing of such risks, which are already embedded in the mortgage rate) as well as possibly other factors, such as any persistence in the mark-up in mortgage rates over MBS yields because of market concentration.

More specifically, our mortgage rate pricing model regression equation can be written as:

$$r_M = \beta_1 + \beta_2 r_{MBS} + \beta_3 FICO + \beta_4 Capacity + \mu$$

where the coefficient on the MBS yield would be expected to be close to one, and μ is the residual.²⁵

²⁵ We also incorporate lags into the regression specification for mortgage rates in order to reflect the timing for when information becomes available to investors. For example, the unemployment rate is lagged one month to reflect the

Our coefficient estimates for the mortgage rate regression are given in the top panel of figure 6. The coefficients each have the expected sign and each one is statistically significant at the 99 percent confidence interval. Also note that the coefficient on the MBS yield is significantly less than one, suggesting that a change in the MBS yields is never fully incorporated into the mortgage rate, that is, there is an incomplete pass-through from changes in MBS yields to changes in mortgage rates. Finally, as shown in the bottom panel, the residuals of the regression are stationary. Using this regression, a decline of 100 basis points in the MBS yield would translate to decline of 81 basis points in the mortgage rate, all other things equal.

The calculated effects outlined above provide evidence that Federal Reserve MBS purchases do place downward pressure on MBS yields (and on U.S. mortgage rates). But, of course, during the actual implementation of the large-scale asset purchase programs, the gyrations in market expectations about the economic recovery and monetary policy also were playing major roles in the determination of interest rates. Consequently, better data and more research are needed to adequately capture the short-term supply and demand dynamics of the MBS markets and their linkages to primary mortgage rates. Overall, however, our findings suggest that it takes a sizeable purchase program by the Federal Reserve to move the mortgage rate down by a noticeable amount.²⁶

6. Federal Reserve LSAPs and the Required Return on MBS

The secondary mortgage market in the United States is primarily focused on the hedging of the interest rate and prepayment risks associated with 30-year fixed rate mortgages that do not allow the lender to charge directly for the option to prepay the mortgage early.²⁷ Suppose a mortgage is incorporated into an agency MBS. The holder of the MBS bears no credit risk (because the MBS is guaranteed by Fannie Mae, or by Freddie Mac, both of which are government-sponsored enterprises (GSEs)), but still must manage interest rate risk and prepayment

most current value that would be known at any specific date.

²⁶ Unless perhaps financial markets are in disarray, as was the case in November 2008 and as discussed in Hancock and Passmore, 2011.

²⁷ In particular, more than 90 percent of agency MBS trading volume occurs in a forward market referred to as the “To-Be-Announced,” or TBA, market. This is also where the Federal Reserve has purchased most of its MBS holdings. See Vickery and Wright (2013).

risk associated with holding MBS. In the event that the homeowner prepays the mortgage, the resulting cash payment is sent to the holders of the agency MBS on a pro-rata basis. Although the holders of the MBS are uncertain about when such a prepayment will be received, the prepayment is more likely when mortgage rates become lower than the original rate.

MBS yields are based on the compensation that investors need to compensate them for their funding costs, hedging costs, prepayment risks, and other costs associated with holding MBS.²⁸ For hedging costs, private investors in MBS often purchase an interest rate swap, for which they pay the fixed-portion of the swap and receive the short-term variable payment; almost always a payment based on the three-month Libor rate. Using a long-term swap to hedge mortgage interest rate risk would still leave the holder of the MBS with a significant maturity mismatch if their underlying funding structure is not similar to three-month Libor. That is, the investor would still likely continue to have significant basis risk (since its liability structure would probably be more sensitive to Treasury rates than to the average swap rates). In addition, the investor must account for the “rollover risk,” which is the risk that the swaps that the investor is counting on for hedging interest rate and basis risks will become more expensive in the future should they expire before the mortgage is prepaid.

These risks, along with other risks (such as “model risks”) are all captured by the MBS-Swap spread. All of these risks, along with the swap spread itself are influenced by the Federal Reserve’s purchases of MBS and of Treasury securities. We average across the five-year and ten-year swap rates to approximate these average costs of a swap with a similar duration as an MBS security. Durations for MBS are notoriously difficult to calculate, but averaging the five-year and ten-year swap rate is a common industry practice for approximating the relevant swap yield because hedges are usually built using these two maturities, which have far greater liquidity than other swaps with maturities between 5 and 10 years.

We estimated a regression for the MBS Yield-Swap Rate spread using the same regression variables as described earlier for the MBS yield regression (figure 7). The announcement and

²⁸ Gabaiz, Krishnamurthy, and Vigneron (2007) provide theory and empirical evidence that mortgage prepayment risk carries a positive risk premium dependent on the amount of prepayment risk borne by mortgage investors. The theory requires the MBS market be segmented and that a class of arbitrageurs who operate predominantly in that market determine the prepayment risk premium. This theory fits into the preferred habitat approach for rationalizing the effects of Federal Reserve asset purchases on longer-term rates. See discussion below on the portfolio rebalancing channel.

market share variables generally lowered this spread. We also perform the same simulation and decomposition as described earlier, but used the MBS-Swap spread. As show on figure 8, the MBS-Swap spread falls about 10 basis points over six months, with the decline driven primarily by the increases in the stock of Federal Reserve MBS holdings. These simulations suggest that MBS and Treasury LSAPs lowered the compensation paid to investors for the risks of holding MBS.

7. Conclusion

We provide an empirical analysis of the effects of the Federal Reserve's large-scale asset purchases on MBS yields and U.S. mortgage rates. Assessing the effects of these Federal Reserve open market operations is difficult because this type of monetary policy accommodation operates through many transmission channels, including a signaling channel that may alter expectations of market participants and result in the anticipation of more asset purchases, as well as liquidity and portfolio rebalancing channels that may result from scarcities of long-term assets and the withdrawal of duration from asset markets. In short, the market both anticipates LSAP announcements and tries to calculate potential LSAP effects.

The decline in the MBS yields after the initial announcement of a large-scale asset program generally seems to not fully capture the actual effects of the large-scale security purchases. Our Federal Reserve market share variables were significant determinants of MBS yields, even after accounting for announcement adjustments on MBS yields by market participants. Moreover, market participants also failed to substantially anticipate FOMC announcements with respect to LSAPs, suggesting that FOMC announcements can surprise market participants. In turn, significantly lower MBS yields resulted in significantly lower mortgage rates, although the pass-through rate was not 100 percent. Finally, we also find that an MBS and Treasury LSAPs lowered the compensation paid to investors for the risks of holding MBS.

Our findings that the Federal Reserve's long-term asset programs lowered MBS yields and U.S. mortgage rates is consistent with the central bank not "running out of ammunition" even when short-term rates have been forced down to zero. Moreover, evidence of the statistical power of the Federal Reserve market shares for MBS and Treasury securities suggests that event-study-based estimates of the effects of LSAPs may be underestimating their substantial ability to lower mortgage rates. These findings suggest that such LSAPs achieved the FOMC's goal to "put downward pressure on longer-term interest rates, support mortgage markets, and help make broader financial conditions more accommodative."

Table 1
Announcement Descriptions

Order	Date	Announcement	Program	Type
1	11/25/2008	The Federal Reserve will purchase "up to \$100 billion in GSE direct obligations," and "up to \$500 billion in MBS."	QE1	Increase (Increased Purchases)
2	12/01/2008	In a speech, Chairman Bernanke states that the Federal Reserve "could purchase longer-term Treasury or agency securities...in substantial quantities."	QE1	Com (Communication)
3	12/16/2008	The FOMC "anticipates...exceptionally low levels of the federal funds rate for some time." It also "stands ready to expand its purchases of agency debt and mortgage-backed securities...[and] is also evaluating the potential benefits of purchasing longer-term Treasury securities."	QE1	Com
4	01/28/2009	The FOMC "is prepared to purchase longer-term Treasury securities."	QE1	Com
5	03/18/2009	The FOMC "anticipates...exceptionally low levels of the federal funds rate for an extended period." It will also purchase "up to an additional \$750 billion of agency mortgage-backed securities," "up to \$100 billion" in agency debt, and "up to \$300 billion of longer-term Treasury securities over the next six months."	QE1	Increase
6	08/12/2009	The FOMC "decided to gradually slow the pace" of Treasury purchases ("up to" language with reference to Treasury purchases is also removed).	QE1	Decrease (Decreased Purchases)
7	09/23/2009	The FOMC "will gradually slow the pace of" of agency MBS purchases ("up to" language with reference to agency MBS purchases is also removed).	QE1	Decrease
8	11/04/2009	The FOMC "will purchase...about \$175 billion of agency debt" ("up to" language with reference to agency debt is also removed).	QE1	Increase

Source: Woodford, Michael (2012) "Methods of Policy Accommodation at the Interest-Rate Lower Bound." Jackson Hole Symposium: "The Changing Policy Landscape"

Table 1 (Continued)
Announcement Descriptions

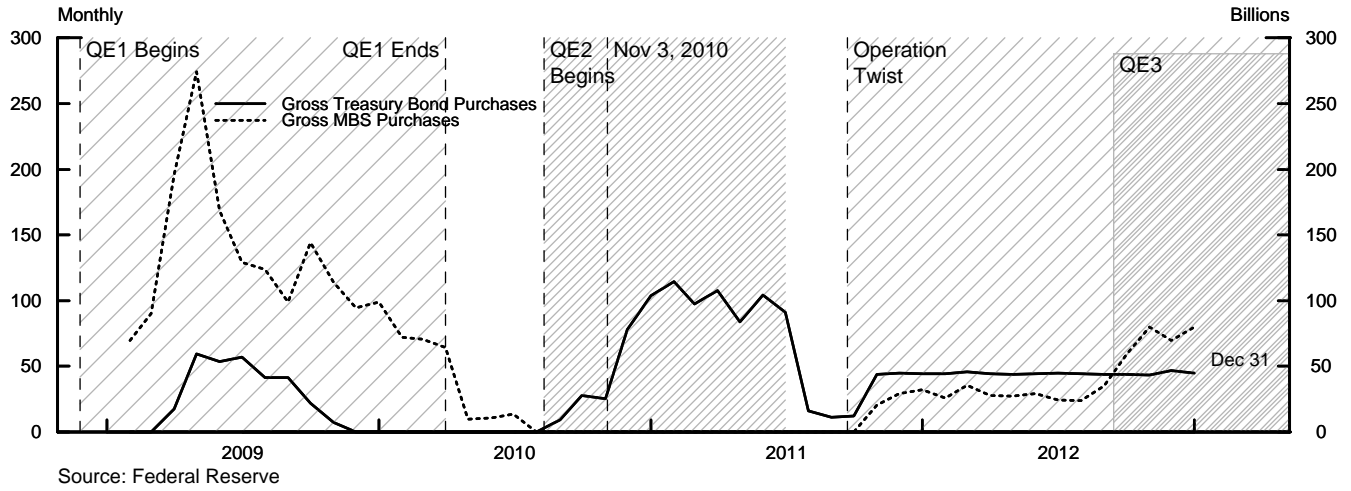
Order	Date	Announcement	Program	Type
9	08/10/2010	The FOMC will reinvest "principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities."	QE2	Increase
10	08/27/2010	In a speech, Chairman Bernanke announces that "additional purchases of longer-term securities...would be effective in further easing financial conditions."	QE2	Com
11	09/21/2010	The FOMC "is prepared to provide additional accommodation if needed."	QE2	Com
12	11/03/2010	The FOMC "intends to purchase a further \$600 billion of longer-term Treasury securities by the end of the second quarter of 2011, at a pace of about \$75 billion per month."	QE2	Increase
13	09/21/2011	The FOMC "intends to purchase, by the end of June 2012, \$400 billion of Treasury securities with remaining maturities of 6 years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less."	OT	Increase
14	06/20/2012	The FOMC "decided to continue through the end of the year its program to extend the average maturity of its holdings of securities." An accompanying statement by the Federal Reserve Bank of New York clarifies that this continuation will "result in the purchase, as well as the sale and redemption, of about \$267 billion in Treasury securities by the end of 2012."	OT	Increase
15	09/13/2012	The FOMC "will increase the Committee's holdings of longer-term securities by about \$85 billion each month through the end of the year," including "purchasing additional agency mortgage-backed securities at a pace of \$40 billion per month."	QE3	Increase
16	12/12/2012	The FOMC will continue purchasing "at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored."	QE3	Com

Source: Woodford, Michael (2012) "Methods of Policy Accommodation at the Interest-Rate Lower Bound." Jackson Hole Symposium: "The Changing Policy Landscape"

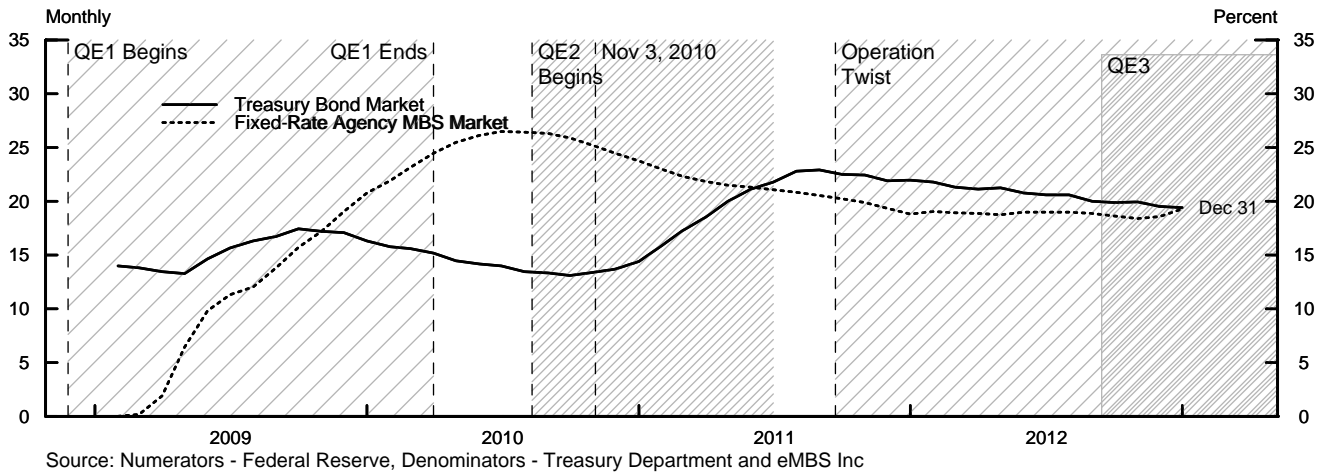
Figure 1

Scope of Quantitative Easing Programs

Federal Reserve MBS and Treasury Purchases



Federal Reserve Market Share of MBS and Treasury Securities



Excess Reserves in the Banking System

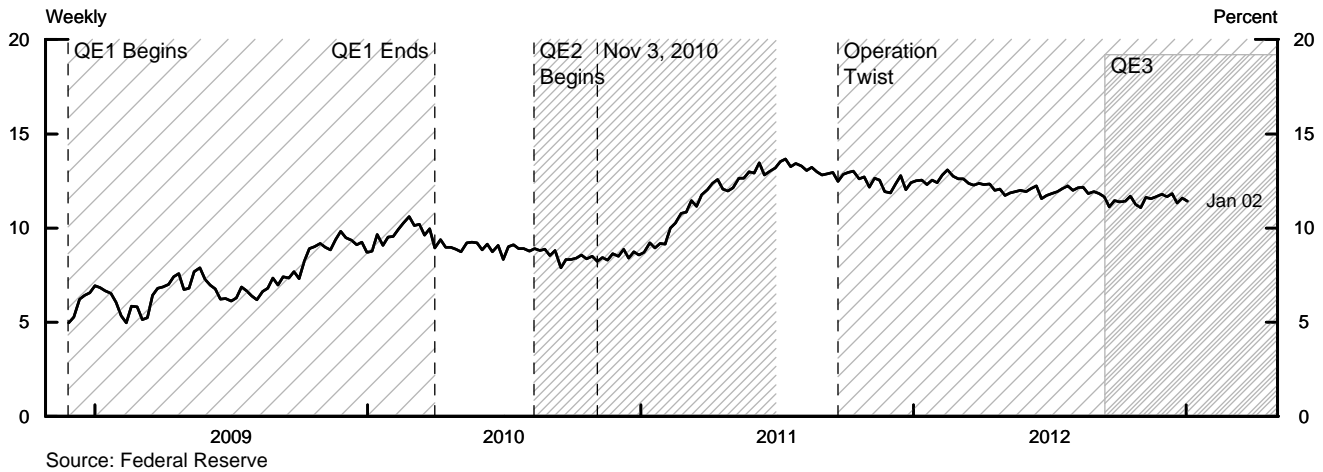


Figure 2
Mortgage Rate and MBS Yield



Source: Mortgage rate - Freddie Mac, MBS Yield - Derived from Bloomberg

Figure 3

Probability of Federal Reserve LSAP Announcement

Estimated Ten-Year Treasury Rate
for Pre-Crisis Period

Variable	Parameter Estimate (1)	Standard Error (2)	t Value (3)
(1) Intercept	6.93 ***	0.11	61.27
(2) Inflation (4-week Mov Avg)	0.14 ***	0.03	4.61
(3) Unemployment (12-week Mov Avg)	-0.52 ***	0.02	-31.21

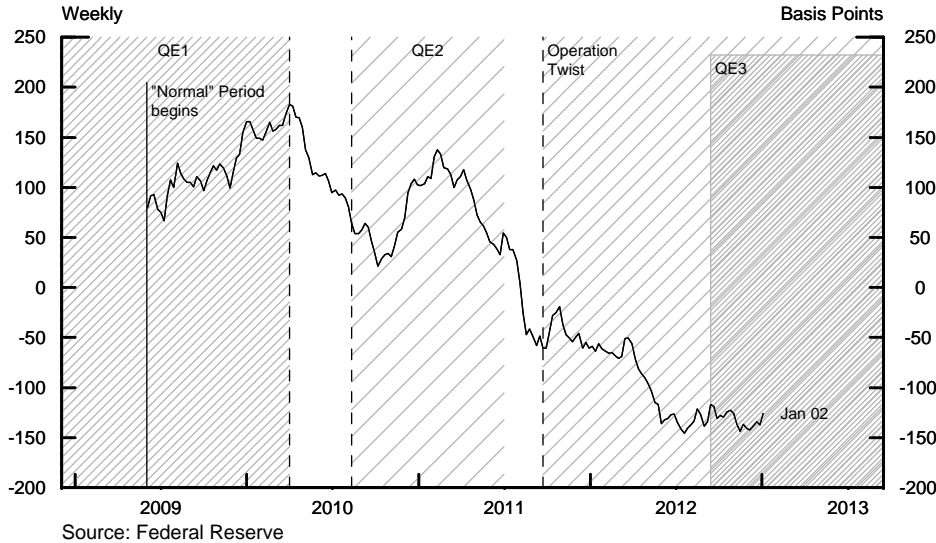
Adjusted R-Squared = 0.400
Daily Data from April 2, 2001 to December 29, 2006 (n = 1500)

Estimated Probability of an FOMC Announcement
(Derived from Probit Specification)

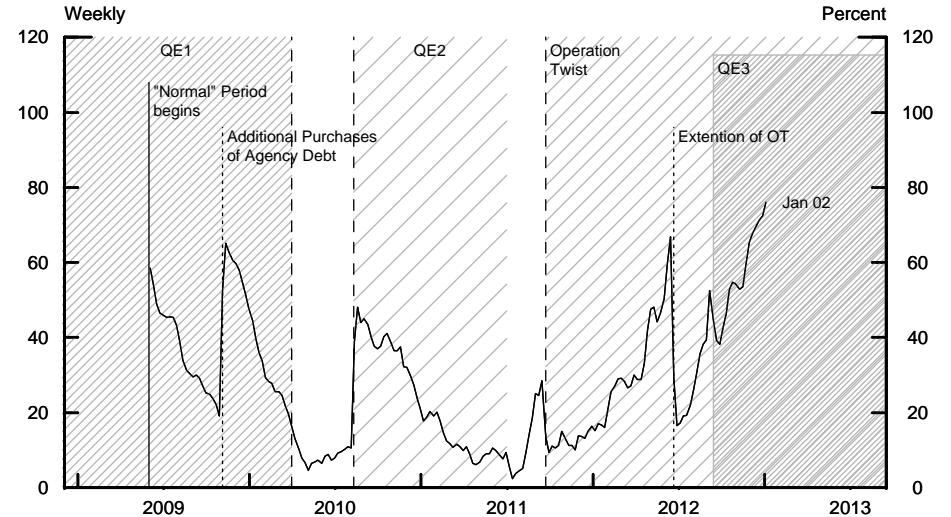
Variable	Parameter Estimate (1)	Standard Error (2)	t Value (3)
(1) Intercept	0.725	0.564	1.284
(2) Days times Treasury Residual	-0.006 **	0.002	-2.507
(3) European Sovereign CDS Spreads	-0.291 **	0.141	-2.060

FOMC meetings from November 3, 2008 to December 31, 2012 (n=33)

Out-of-Sample Treasury Residual



Estimated Probability of Announcement



Asterisks *** represent significance at the 99% confidence level, ** at the 95% level, and * at the 90% level.

Source: Ten-Year Treasury Rate - Federal Reserve; Inflation Compensation - Federal Reserve estimate based on data from Barclays, Federal Reserve Bank of New York; Unemployment - BLS; FOMC Announcement (Days) - Woodford (2012)

Figure 4
MBS Yield Regression

Estimating the MBS Yield

		<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>t Value</i>
<i>Variable</i>	(1)	(2)	(3)	
(1) Intercept	8.06 ***	1.20	6.69	
(2) Federal Reserve Market Share of MBS	-7.55 ***	2.79	-2.71	
(3) Federal Reserve Market Share of Treasury Securities	-8.89 **	4.39	-2.02	
(4) European Sovereign CDS Spreads	-0.18 ***	0.05	-3.54	
(5) Estimated Probability of Announcement	-2.73 ***	0.45	-6.12	
(6) Announcement Effect	-1.35 ***	0.32	-4.19	

Adjusted R-Squared = 0.598				
Weekly Data from May 27, 2009 to December 26, 2012 (n = 188)				

Asterisks *** represent significance at the 99% confidence level, ** at the 95% level, and * at the 90% level.
 See footnote 24 for an explanation of the time period chosen.

Source: Federal Reserve Treasury and MBS Holdings - Federal Reserve
 Total Treasuries Outstanding - Treasury Department
 Total MBS Outstanding - eMBS Inc

Figure 5

Cummulative Effects of \$50 Billion Per Month of Large-Scale Asset Purchases on MBS Yield

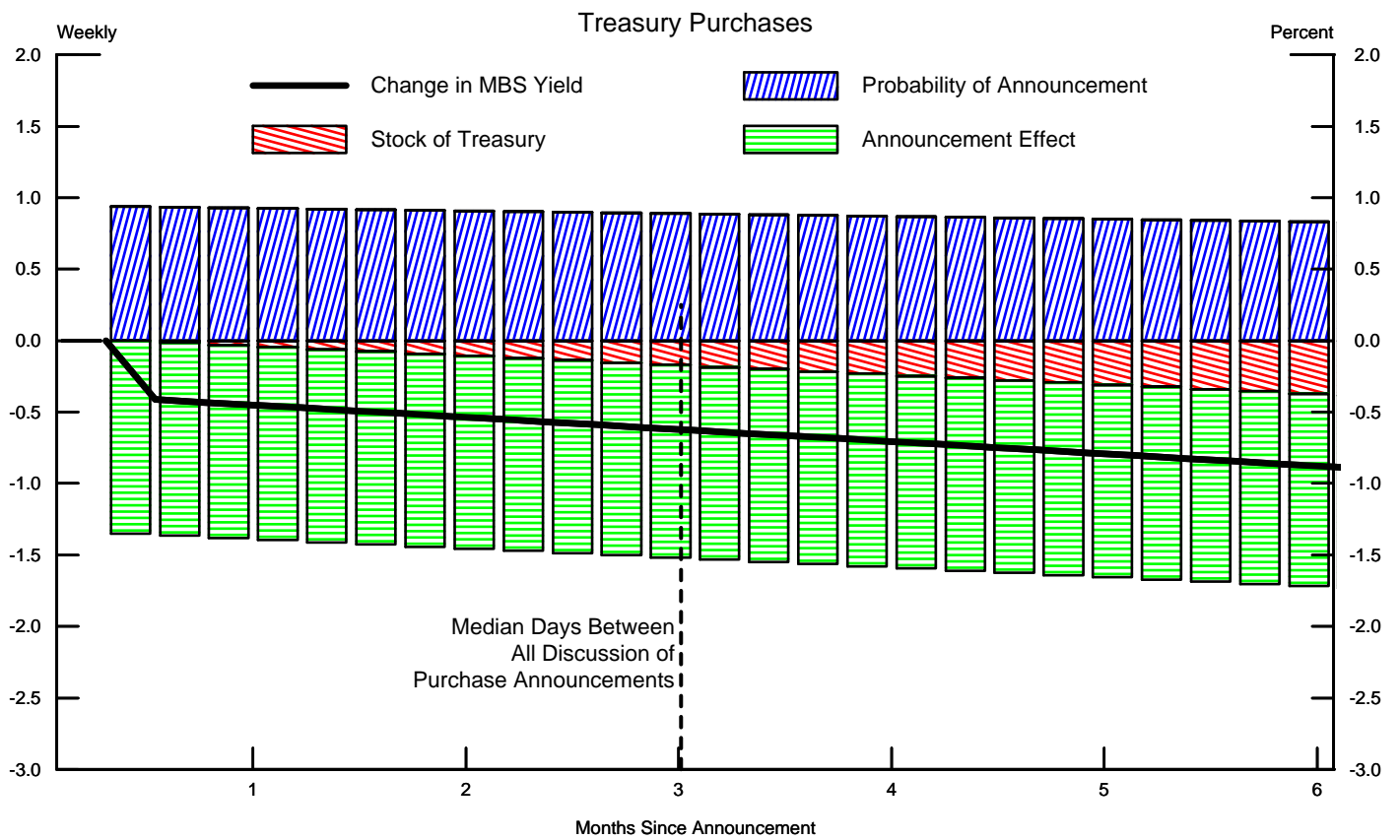
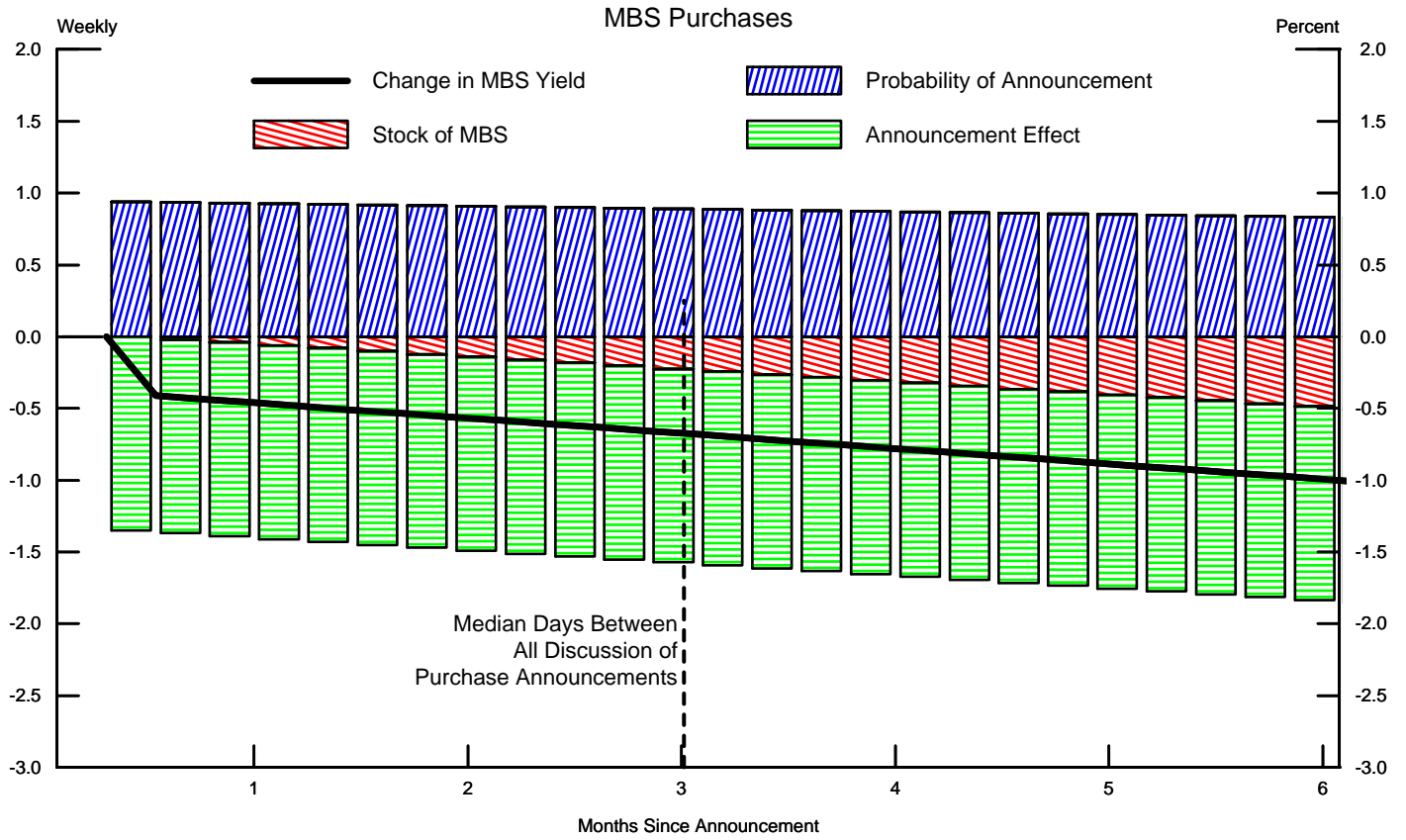
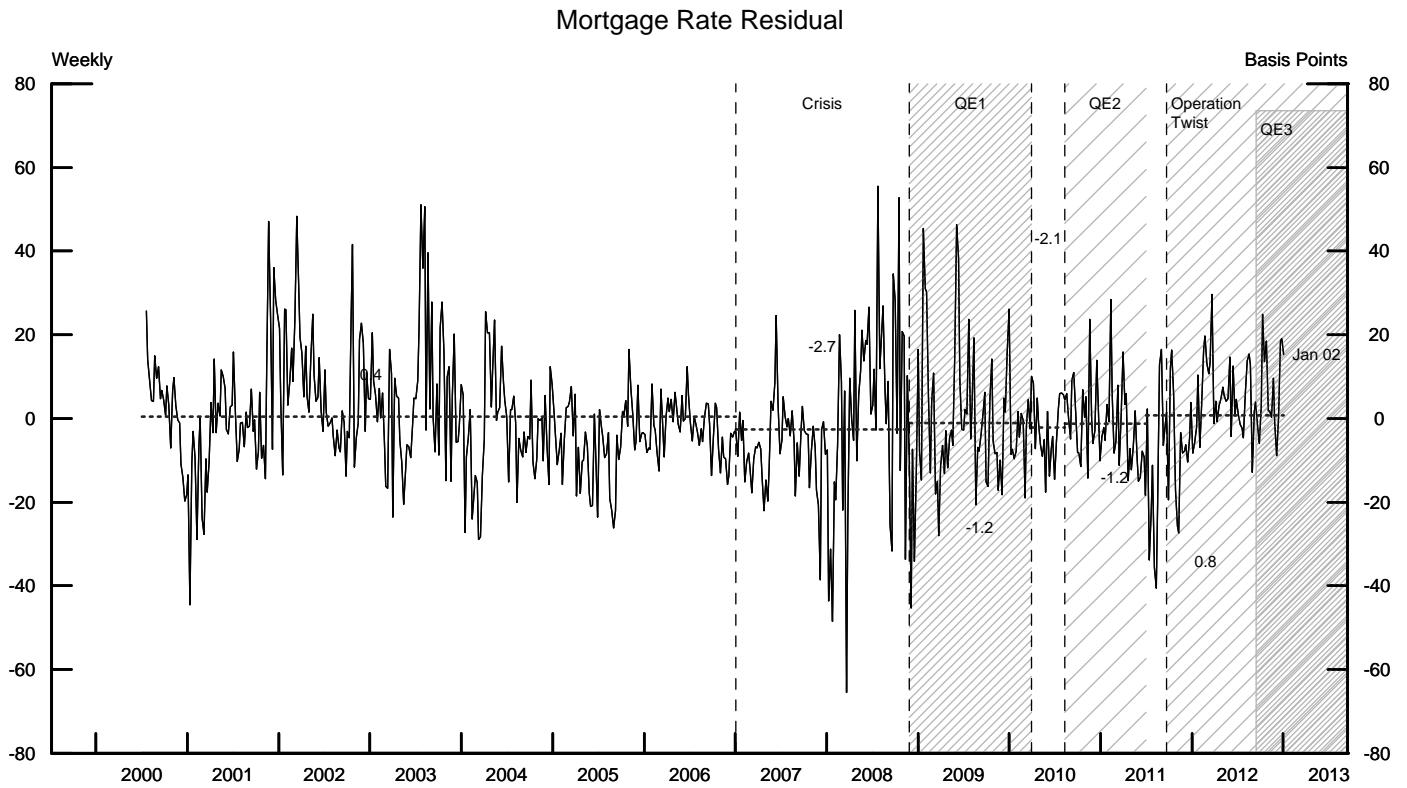


Figure 6
Mortgage Rate Regression

Variable	Parameter Estimate (1)	Standard Error (2)	t Value (3)
(1) Intercept	6.39 ***	1.06	6.01
(2) MBS Yield (Weekly Average)	0.81 ***	0.01	59.00
(3) FICO Score	-6.23 ***	1.30	-4.80
(4) Capacity	0.01 ***	0.00	5.27

Adjusted R-Squared = 0.981
Weekly Data from July 26, 2000 to December 26, 2012 (n = 649)



Asterisks *** represent significance at the 99% confidence level, ** at the 95% level, and * at the 90% level.

Source: Mortgage Rate - Freddie Mac
MBS Yield - Derived From Bloomberg
FICO - Derived From CoreLogic
Capacity - Mortgage Bankers Association

Figure 7
MBS Yield -- Swap Rate Spread Regression

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>t Value</i>
<i>(1)</i>	<i>(2)</i>	<i>(3)</i>	
(1) Intercept	2.00 ***	0.33	6.09
(2) Federal Reserve Market Share of MBS	-1.72 **	0.76	-2.26
(3) Federal Reserve Market Share of Trsy	-3.15 ***	1.20	-2.62
(4) European Sovereign CDS Spreads	0.04 ***	0.01	2.97
(5) Estimated Probability of Announcement	-0.57 ***	0.12	-4.66
(6) Announcement Effect	-0.17 *	0.09	-1.89

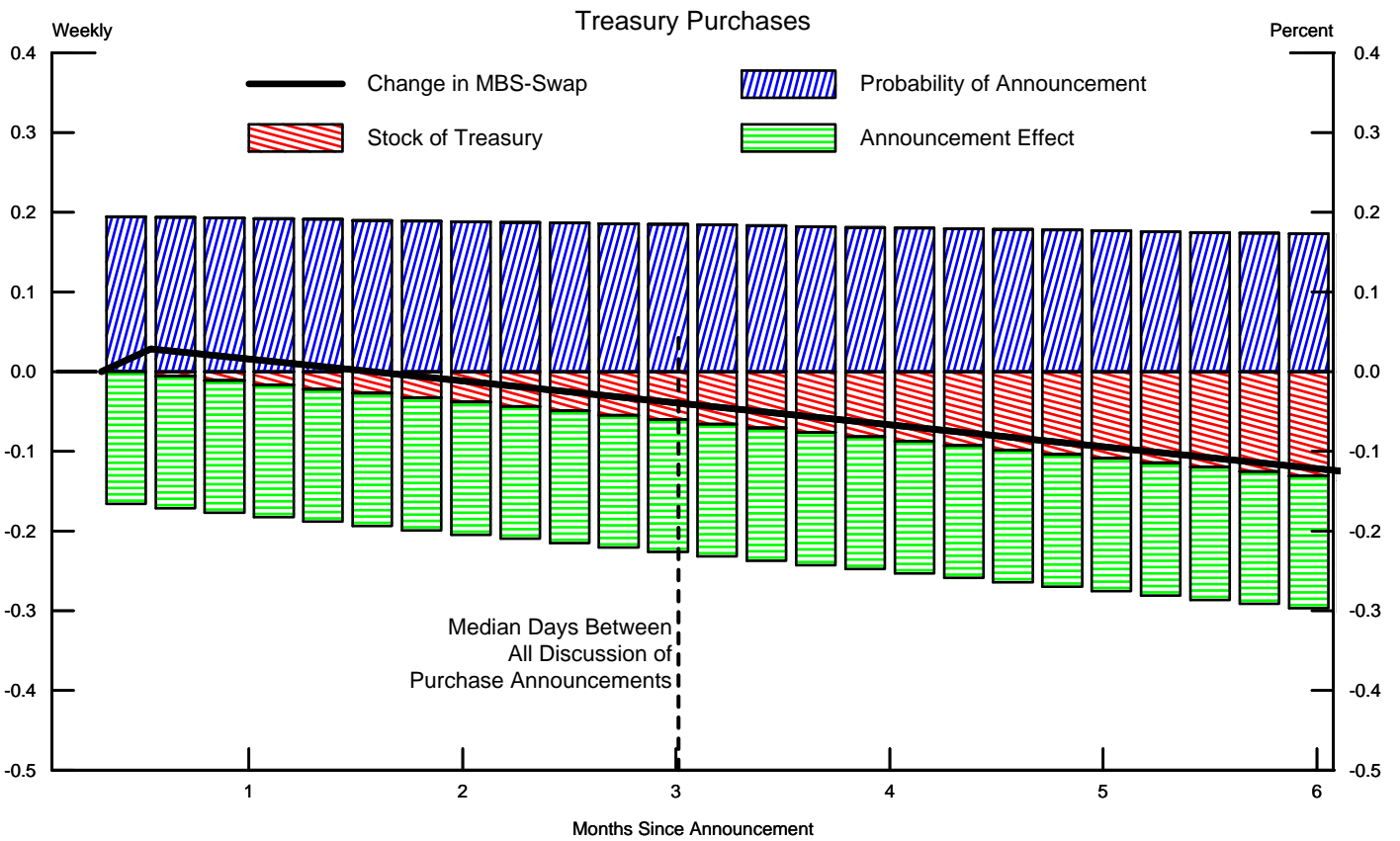
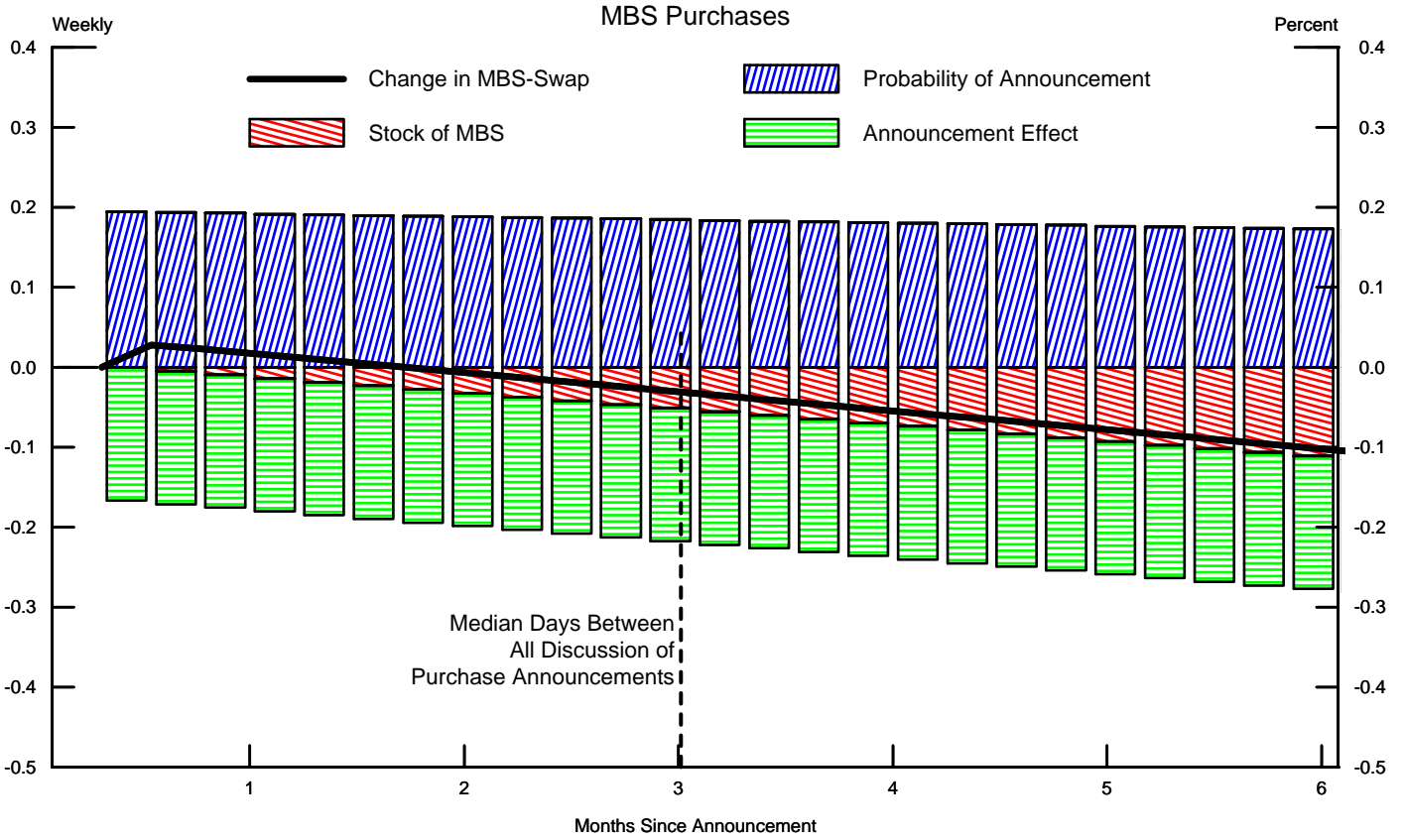
Adjusted R-Squared = 0.251			
Weekly Data from May 27, 2009 to December 26, 2012 (n = 188)			

Asterisks *** represent significance at the 99% confidence level, ** at the 95% level, and * at the 90% level. See footnote 24 for an explanation of the time period chosen.

Source: Federal Reserve Treasury and MBS Holdings - Federal Reserve
 Total Treasuries Outstanding - Treasury Department
 Total MBS Outstanding - eMBS Inc

Figure 8

Cummulative Effects of \$50 Billion Per Month of Large-Scale Asset Purchases on the MBS Yield -- Long Swap Rate Spread



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