Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond

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Abstract

This paper provides an overview of unconventional monetary policy as implemented by the U.S. Federal Reserve after the global financial crisis. First, it reviews the key features of the Fed's Quantitative Easing and Forward Guidance policies. Second, it discusses the mechanisms through which the two policies may have affected financial markets, institutions, and the overall economy. Third, it surveys the evidence on the policies' financial and economic impacts. Fourth, it considers some of the policies' unintended side effects. The paper concludes with some thoughts on how unconventional monetary policy might be used in the future.

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Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond

In November 2008, the Federal Reserve faced a deteriorating economy and a financial crisis. The federal funds rate had already been reduced to virtually zero. Thus, the Federal Reserve turned to unconventional monetary policies. Through "quantitative easing," the Fed announced plans to buy mortgage-backed securities and debt issued by government-sponsored enterprises. Subsequent purchases would eventually lead to a five-fold expansion in the Fed's balance sheet, from $900 billion to $4.5 trillion, and leave the Fed holding over 20 percent of all mortgage-backed securities and marketable Treasury debt (as reported in the Fed's Z.1 release, table L.211, and Treasury Bulletin, table OFS-1). In addition, Fed policy statements in December 2008 began to include explicit references to the likely path of the federal funds interest rate, a policy that came to be known as "forward guidance."

The Fed ceased its direct asset purchases in late 2014. Starting in October 2017, it has allowed the balance sheet to shrink gradually as existing assets mature. From December 2015 through June 2018, the Fed has raised the federal funds interest rate seven times.

Thus, the time is ripe to step back and ask whether the Fed's unconventional policies had the intended expansionary effects—and by extension, whether the Fed should use them in the future.

The aim of this paper is to take stock of what we have learned about unconventional monetary policy in the nine years since its inception, and to highlight some open questions. It begins with a review of the key features of unconventional policy. Next, it discusses the transmission of unconventional policy to financial markets, institutions, and the economy more broadly. Then it addresses the question of effectiveness with a selective survey of empirical work on the financial and economic impact of these policies, and it takes up the issue of the policies' unintended side effects. It concludes with some thoughts on the shape unconventional monetary policy might take in the future.

What Were the Unconventional Federal Reserve Policies?

Quantitative Easing

Quantitative easing refers to a set of four asset purchase programs: the three Large Scale Asset Purchases (LSAPs), commonly known as QE1, QE2, and QE3; and the Maturity

Extension Program (MEP), also known as the second "Operation Twist".[2,3] Table 1 summarizes the key features of these programs.

QE1 was announced in November 2008. Initially, it was limited to purchasing $100 billion of debt issued by the government-sponsored enterprises Fannie Mae, Freddie Mac and Ginnie Mae, plus $500 billion in agency-backed mortgage-backed securities.[4] Its stated purpose was to "reduce the cost and increase the availability of credit for the purchase of houses." On March 18, 2009, the Federal Open Market Committee announced that it would expand its purchases of agency debt and mortgage backed securities, and would also purchase $300 billion of longer-term Treasury securities "to help improve conditions in private credit markets" more generally.

QE2 was announced on November 3, 2010. The program entailed the purchase of $600 billion in longer-term Treasuries, but no agency debt or mortgage backed securities.

The Maturity Extension Program was announced on September 21, 2011. The program initially involved the purchase of $400 billion of 6- to 30-year Treasuries, accompanied by the sale of the same quantity of 1- to 3-year securities, with the intention "to put downward pressure on longer-term interest rates and help make broader financial conditions more accommodative." The Fed announced an extension of the program June 20, 2012, which ultimately amounted to $667 billion. In contrast to the three large-scale asset purchases, all of which entailed balance sheet expansions, this program "sterilized" the asset purchases with offsetting asset sales, leaving unchanged the overall size of the balance sheet.

QE3, which commenced in September 2012, initially involved the purchase of $40 billion per month of mortgage-backed securities in a renewed effort to "support mortgage markets." In December, the program was expanded to include $45 billion per month of Treasury securities. Unlike the other three quantitative easing policies, QE3 was open-ended and did not set a dollar limit at the time of the program's launch.

These quantitative easing policies differ in clear ways from conventional monetary policy. For example, Figure 1 shows that quantitative easing drastically enlarged and altered the composition of the Fed's System Open Market Account portfolio. In contrast, the quantitative aspects of conventional policy, in terms of the Fed's balance sheet or the money supply, had always been negligible. The magnitude of the open market operations (essentially, temporary asset purchases) required to move the federal funds rate was

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[2] Excluded from quantitative easing are the assets acquired by the Federal Reserve in its capacity as lender of last resort, such as the asset-backed commercial paper purchased as part of the Commercial Paper Funding Facility, which was operated from October 2008 to February 2010 in seeing to avert a liquidity crisis.

[3] The first "Operation Twist" was a short-lived episode in 1961.

[4] To put this into perspective, in the five years prior to the crisis, the Fed would purchase $2.75 billion of Treasury securities in a typical month.

vanishingly small—virtually undetectable in the Fed balance sheet (Friedman and Kuttner 2010).

Another difference is that the goal of quantitative easing was not stated in terms of an explicit interest rate target.[5] But because a $100 billion purchase of mortgage backed securities is not necessarily equivalent to a $100 billion sterilized purchase of 10-year Treasuries, it is not straightforward to distill the effects of the various quantitative easing programs into an interest rate equivalent.

A common misconception is that the purpose of quantitative easing was to increase bank reserves and the money supply. The Fed's pronouncements clearly contradict this view. For example, in the December 16, 2008, meeting of the Federal Open Market Committee, then-Fed Chair Ben Bernanke characterized the approach of the Bank of Japan as based on the theory that "providing enormous amounts of very cheap liquidity to banks would encourage them to lend and that lending, in turn, would increase the broader measures of the money supply." Contrasting this with the Fed's approach, Bernanke stated, "What we are doing is different from quantitative easing because, unlike the Japanese focus on the liability side of the balance sheet, we are focused on the asset side of the balance sheet."[6]

Forward Guidance

The Fed's conventional modes of communication already providing markets with a great deal of information relevant to forming expectations about future policy expectations. FOMC statements and minutes included assessments of economic conditions, for example, along with the economic projections of board members and regional bank presidents. What distinguished forward guidance was its explicit reference to the likely path of the target interest rate. The tactic sought to communicate a lengthening of the anticipated period of time over which interest rates were likely to remain low.

The early forward guidance statements were qualitative and vague. The December 16, 2008, statement, said that rates were likely to remain low for "some time." The March 18, 2009, statement referred to an "extended period." The statements used the word "anticipate" and were conditioned on unspecified "economic conditions." In 2011, forward guidance began to involve of calendar-based statements and explicit time horizons. But the horizons were repeatedly extended as the economy languished, and continued to be framed in terms like "are likely" and conditioned on economic developments.

In the Federal Open Market Committee statement of December 12, 2012, forward guidance became even more explicit. It said that the low interest rate policy would remain in place so

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[5] In this respect, the Fed's version of quantitative easing differs from the Bank of Japan's current "QQE with Yield Curve Targeting" policy, and from a proposal originally floated by Ben Bernanke (2002).

[6] Bernanke's distinction notwithstanding, I will follow common usage in this paper in referring to the Fed's policies as "quantitative easing."

long as unemployment remained above 6.5 percent and the inflation forecast was below 2.5 percent.

With the unemployment rate at 6.7 percent, the Federal Open Market Committee in December 2013 began to include in its policy statement language indicating its intention to keep the federal funds rate low "well past the time that the unemployment rate declines below 6.5 percent." As time progressed, the reversion to qualitative, open-ended forward guidance led to considerable speculation regarding the date of the first rate increase. "Liftoff" eventually occurred 18 months after the unemployment rate crossed the 6.5 percent threshold, by which time the rate had declined to 5 percent.

Monetary Policy Transmission

Actions by the Federal Reserve affect a constellation of interest rates and asset prices, which in turn influence spending decisions by households and firms, and lending decisions by financial institutions. Many of these mechanisms, but not all, operate in the same way under conventional and unconventional monetary policies. But the arrival of unconventional policies has prompted a reexamination of the linkages between monetary policy and financial markets and led to renewed interest in models characterized by imperfect substitutability between assets.

The transmission of conventional monetary policy

Before its reduction to virtually zero in late 2008, the federal funds rate was the sole tool of US monetary policy. Little or no economic activity depends directly on the funds rate, however, as it applies only to overnight borrowing and lending between banks. Instead, the funds rate affects spending indirectly, through a number of distinct channels.

One is through the interest rates on longer-maturity obligations, such as mortgages and corporate bonds, which are more relevant to spending decisions than the overnight funds rate. Interest rates also affect the prices of assets, such as equities and houses, creating wealth effects that influence households' spending decisions. Similarly, interest rate changes affect imports and exports through their impact on the exchange rate.

It is important to note that long-term rates, asset prices and the exchange rate depend on the market's forecast of *future* short-term rates, not just the current funds rate target. Therefore, Fed communication—announcements, speeches, press conferences and the like—will affect spending to the extent that they provide information about the likely path of future policy.

Conventional policy can also affect spending through the banking system. In the traditional bank lending channel advanced by Kashyap and Stein (1994), the increase in bank reserves associated with expansionary policy increases loan supply. For a bank that finances long-term assets with short-term liabilities, a rate reduction will increase the market value of its equity, promoting lending. (Working in the opposite direction, lower rates crimp banks' net interest margin, which tends to reduce loan supply.)

Finally, in the credit channel described by Bernanke and Gertler (1995), expansionary policy ameliorates informational frictions and reduces firms' external finance premiums, thus enhancing the real effects of rate cuts.

The Transmission of Forward Guidance

Forward guidance affects interest rates and asset prices by conveying information about the likely trajectory of future interest rates. In that respect, it does not differ qualitatively from other forms of Fed communication that hint at future policy. The main difference is that the interest rate path communicated as part of forward guidance was more explicit than under the conventional policy regime.

There are two reasons why forward guidance may affect interest rate expectations. One interpretation, dubbed "Odyssean" by Campbell, Fisher, and Evans (2012), is that forward guidance would commit the Fed to pursue the time-inconsistent policy of allowing the inflation rate to exceed the Fed's objective for some period of time. A credible commitment to higher inflation in the future would reduce future short-term real interest rates (Eggertsson and Woodford 2003). Odyssean forward guidance is therefore unambiguously expansionary.

Alternatively, forward guidance may convey information without implying a commitment, the case Campbell, Evans, Fisher, and Justiniano (2012) referred to as "Delphic." There are two possibilities as to the type of information that could be transmitted. One possibility is that an expansionary forward guidance announcement reveals to the private sector proprietary Fed information that the economy is weaker than previously thought, which in turn implies that interest rates are likely to remain low for a longer time. However, as noted by Woodford (2012), if current real expenditures depended on expected future income, then an announcement that led to a more downbeat view of the economy could be contractionary.

A second way in which forward guidance could affect expectations is by communicating information about the Fed's policy rule. This channel may be especially important when markets had no clear sense of how economic conditions would affect how long interest rates would remain near zero. Consistent with this view, using information gleaned from the New York Fed's surveys of primary dealers, Femina, Friedman, and Sack (2013) showed that successive forward guidance statements pushed back the date of the expected first interest rate increase. Also consistent with this view is the finding by Swanson and Williams (2013) of a decreased sensitivity, beginning in late 2011, of medium-term interest rates to macroeconomic news.

The Transmission of Quantitative Easing

Quantitative easing entails the use of the Fed's balance sheet to influence long-term and private sector interest rates. This could occur through three mechanisms: imperfect substitutability, signaling about future policy, and improvements in financial balance sheets.

If assets are perfect substitutes, then arbitrage will mean that all assets have equal expected returns. But with imperfect substitutability, each asset class has it own downward-sloping demand curve, allowing changes in the relative supplies of assets to affect prices and yields. This supply-and-demand mechanism is what accounts for portfolio balance effects that were integral to macro models from the 1960s and 1970s, such as those developed by Tobin (1963).

Imperfect asset substitutability may arise from two sources. One comes from the fact that the prices of long-maturity bonds are more sensitive to interest rate fluctuations than those with shorter maturities. Investors with an aversion to interest rate risk will require a higher expected return on long-term bonds, relative to what they would have earned from investing in short-term debt (a "term premium"). Using asset purchases to reduce the supply of long-term bonds should therefore lower their yields by narrowing the term premium.

Market segmentation can also underpin imperfect substitutability. This may arise from investors' preferences for specific types of assets or "preferred habitats" (as hypothesized by Modigliani and Sutch 1966), or by incentives that investors have to hold a minimum share of portfolios in a certain form like securities free from default risk. Vayanos and Vila (2009), for example, developed a model incorporating features of both preferred habitat and portfolio balance models.

Quantitative easing could also affect interest rates by sending a signal about future policy. The idea is that significant purchases of long-maturity bonds signal the Fed's intention to keep the policy rate interest near zero for a longer period of time. As with forward guidance, there are both Delphic and Odyssean interpretations of how the signaling channel could operate. One Delphic view is that asset purchases reveal a downgrading of the Fed's view of economic conditions, and thus should lead to expectations of lower future rates. Another is that signaling conveys information about a change in the Fed's policy rule—for example, that it is placing a higher weight on unemployment or lower-than-intended inflation. The Odyssean interpretation is that a large balance sheet would provide a strong incentive for the Fed to maintain a highly expansionary policy for a longer period of time than it might otherwise have desired, perhaps because the Fed would want to sell of the assets it owns before raising rates.

In addition to putting downward pressure on interest rates, asset purchases also may have stimulated spending by increasing loan supply. The purchases effectively raised banks' capital ratios by increasing the value of the existing assets on their balance sheets. In addition, the purchases of mortgage-backed securities (especially under QE1, when many investors were anxious to reduce their exposure to housing-related risk) increased the liquidity of the market for those securities. Both mechanisms would have made banks more willing to lend.

Unconventional Monetary Policy and Interest Rate Effects

The main challenge in assessing the impact of monetary policy is isolating exogenous policy changes that can be used to identify the policies' causal effects.[7] In the study of conventional monetary policy, the monetary policy "shocks" used to identify the causal effects of changes in the federal funds rate are typically modeled as deviations from the Fed's normal response to economic conditions, most commonly derived from a structural vector autoregression econometric model.

Assessing the impact of unconventional policy is more difficult than it is for conventional policy, for at least two reasons. First, it is not clear what variable to use as a summary measure of monetary policy, given the heterogeneity of the asset purchases and differences in the framing of the forward guidance announcements. Second, defining "shocks" is problematic. Because the financial crisis was such a singular event, it is hard to know what the Fed's "normal" response to it would have been. And in any case, in gauging the macroeconomic effects of unconventional policy, the comparison to a "no policy" counterfactual will be more relevant than one that looks at deviations from the usual policy rule.

Given these obstacles, it is not surprising that research on quantitative easing and forward guidance has tended to focus narrowly on the policies' effects on the interest rates on Treasury bonds and mortgage backed securities, rather than on their ultimate macroeconomic impact.[8] The two most common approaches to assessing the interest rate effects to are high-frequency event studies and time series models of term premiums, both of which have have their limitations.

Event studies

A typical event study for estimating the effects of unconventional monetary policies on interest rates examines changes in bond yields over a one-two day window around which the policies are announced. This approach relies on two identifying assumptions. The first is that the announcement was unanticipated. This seems plausible for the early stages of the first large scale asset purchases. However, lacking a market-based measure of financial markets' expectations, such as the prices of federal funds futures used by Kuttner (2001), there is no satisfactory way to confirm this. Subsequent large scale asset purchases and the Maturity Extension Program may have been anticipated to some extent, in which case the

[7] See Nakamura and Steinsson (2018) for an in-depth discussion of the identification issues bedeviling efforts to measuring effects of monetary policies.

[8] The literature on the interest rate and economic effects of unconventional monetary policy is vast, and the studies mentioned here are intended to illustrate main themes, not to offer a literature review. Bhattarai and Neely (2016) provide a more comprehensive survey.

measured financial market reactions in a few days around the announcement of a policy may understate its true effects.

The second key assumption is that the announcement was not interpreted as revealing the Fed's proprietary information about the state of the economy, which in turn would have affected bond yields. This could be problematic, in light of the Campbell, Evans, Fisher, and Justiniano (2012) finding mentioned earlier that expansionary policy surprises have historically been associated with upward revisions in private-sector unemployment rate forecasts.

Table 2 summarizes the estimated cumulative effects from a selection of event studies. The results vary somewhat across studies, due to differences in the length of the event window, the choice of interest rate data, and the selection of events, but all tell roughly the same story.

The most salient result is that the QE1 announcements had very large, negative effects on long-term interest rates: approximately 100 basis points for Treasuries and mortgage-backed securities and upwards of 150 basis points (depending on the horizon) for agency issues. The reactions represent extreme tail events, the largest one-day changes observed in the entire post-crisis period. The effects of subsequent programs on yields were materially smaller. The estimated two-day effects of the second large-scale asset purchase announcements are in the −30 to −40 basis point range with comparable figures for the Maturity Extension Program. The QE3 announcements appear to have had only a small impact on yields.

Taken together, the event studies suggest that the four policies' cumulative effects on the 10-year Treasury yield totaled at least −150 basis points. The evidence should be interpreted with caution, however. There are five reasons why the results could be inaccurate or not fully generalizable to other situations.

First, QE1 was launched at a time of high stress levels in financial markets. The initial November 25, 2008, announcement cited widening spreads on the debt of government-sponsored entities debt and on the mortgages they guaranteed. It stated that the action was being "taken to reduce the cost and increase the availability of credit for the purchase of houses," saying nothing about long-term interest rates more broadly. Similarly, the December 16, 2008, minutes of the Federal Open Market Committee called attention to soaring risk spreads on corporate bonds and rising premiums for on-the-run Treasuries, and described the functioning of Treasury markets as "impaired." Therefore, much of the impact of the first large scale asset purchases probably came from a restoration of market functioning, rather than a reduction in either expected future interest rates or the term premium.

Second, several announcements of quantitative easing also contained forward guidance. Most conspicuously, the December 16, 2008, and March 18, 2009, announcements both stated an intention to keep the federal funds rate at "exceptionally low levels." Some efforts to disentangle these effects are discussed below.

Third, the paucity of announcements means that the results are sensitive to individual observations. For example, the 51 basis point drop in the 10-year Treasury yield on March 18, 2009, is, by a wide margin, the largest in the past 20 years (the runner-up is only −28 basis points). Excluding this observation reduces the estimated impact of QE1 by more than half. Moreover, the small number of observations is an invitation to "cherry pick" dates, and studies that that find a reason to exclude observations with small or perverse reactions are likely to be biased towards finding larger effects.

Fourth, the statistical precision of the event study approach is unclear. If one makes the dubious assumption of equal variance each day, then it would be legitimate to use the variance of non-event-day changes in assessing the precision of the estimated effects. Dropping this assumption requires using only event days to calculate the variance, which is problematic given the small number of observations.[9]

Fifth, and perhaps most important, it can be hard for an event study to measure persistence. It may take some time before changes in asset supplies are fully reflected in prices and yields (Greenwood, Hanson, and Liao 2016). The dilemma is that an event window of sufficient length to account for a gradual response will include "noise" resulting from the arrival of additional information and events, making it less likely to discern a statistically significant impact of the policy. The findings for QE1 and QE2 summarized in Table 2 are *so* large, however, that they remain clearly discernible (in the sense that the cumulative responses exceed two standard deviations) for at least 1–2 weeks.

Assessing the policies' persistence at longer horizons requires imposing a parametric structure on the responses. In an effort to get at the persistence issue, Wright (2012) estimated a vector autoregression on daily data encompassing all four of the quantitative easing programs (but not distinguishing observations according whether they were associated with forward guidance statements). He detected measurable responses over several weeks, but found that the effects wore off after two to three months.

In another effort, Swanson (2017) addressed the issue of persistence by using a two-factor model to differentiate between the effects of forward guidance and quantitative easing, and also fitted an exponential function to the responses as a way to parameterize the rate of decay. Like Wright (2012), he found that the effects of both policies were relatively short-lived. He also found that dropping the outsize reaction of March 18, 2009, significantly decreased the magnitude but increased the persistence of the effects of the large-scale asset purchases (again illustrating the fragility of results based on a small number of announcements).

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[9] For example, the standard deviation of the cumulative effect of the eight QE1 announcements on the 10-year Treasury yield is 58 basis points. Using the t distribution with 7 degrees of freedom, this gives a 95 percent confidence interval ranging from of –20 to 208 basis points.

Time Series Analysis of Term Premiums

Time series econometric methods can be also used to assess the effects of the large-scale asset purchase on bond yields—and in particular on term premiums. Term premiums cannot be observed directly, however, so estimating the policies' effects requires the additional step of fitting a term structure model to the data.

The "affine term structure models" used for this purpose involve specifying the vector of bond yields over different term structures as a function of a small number of factors, which are assumed to follow a first-order vector autoregressive process. The one-period risk-free interest rate is assumed to be a function of the same factors. The structure means that all co-movements between bond returns of different terms are attributed to the factors, and further implies that only the risk associated with those factors is priced.

Figure 2 plots the fitted 10-year term premium, interpretable as an estimate of the difference between the 10-year Treasury yield and the average of forecast short-term interest rates over the life of the bond, derived from the Kim-Wright (2005) method. Already quite low by historical standards prior to the financial crisis, the term premium declined by approximately 200 basis points from mid-2009 to mid-2012. The premium actually fell into *negative* territory, implying that investors were willing to sacrifice some return for the hedge provided by 10-year Treasuries. The yield and term premium fell more or less in lockstep over the quantitative easing period, and the correlation between monthly changes is 0.97. It seems that that a shrinking term premium accounts for almost the entire decline in the yield of a 10-year bond, with very little attributable to falling interest rate expectations.

The time series method has several advantages over the event study approach. First, it makes use of more information. Rather than relying on a handful of announcements, it uses the entire time path. The underling analytical structure makes possible a quantitative assessment—that is, the yield change, in basis points, for a given $100 billion in asset purchases—which is hard to do in an event study framework. Also, the policies' effects can be estimated regardless of whether asset purchase programs were anticipated.

The identifying assumption underlying this approach is that changes in supplies of assets of a specific term result from factors such as the Treasury's debt management or Fed portfolio allocation decisions and are otherwise unrelated to expected interest rates or term premiums. As an example, Greenwood and Vayanos (2014) cite the drop in the average maturity of outstanding Treasury debt in the 1960s and 1970s, which resulted from a 4.5 percent regulatory ceiling on bonds' coupon rates at that time. There is no evidence that either the Treasury or the Fed (at least pre-quantitative easing) adjusted asset supplies in response to term premiums, so it is probably legitimate to treat the supply variables as exogenous.

The identifying assumption would also be violated if asset supplies and term premiums were both a function of an omitted variable, such as macroeconomic conditions and/or the state of the financial system. This is a concern for the quantitative easing period, when the Fed's asset purchases were clearly an endogenous response to the deteriorating state of the economy (just as the federal funds rate was endogenous before quantitative easing). For

this reason, studies taking this approach generally fit the models to data before quantitative easing occurred.

Table 3 summarizes the findings from four well-known studies looking at the effects of quantitative easing policies on term premiums. Taken together, the studies suggest that the policies collectively reduced the 10-year term premium by as much as 150 basis points—remarkably similar to event-study results surveyed previously.

Gagnon, Raskin, Remache, and Sack (2011) and D'Amico, English, López-Salido, and Nelson (2012) both used reduced-form regressions of the Kim-Wright (2005) term premium on measures of relative asset supplies. The two studies' regressions differ in several respects, such the construction of the supply measures and the inclusion of control variables. Despite these differences, both studies have QE1 subtracting at least 35 basis points from the 10-year term premium. D'Amico, English, López-Salido, and Nelson (2012) put the impact of QE2 at −45 basis points.

Ihrig, Klee, Li, Schulte, and Wei (2012) extended an otherwise standard affine term structure model to include asset supplies as additional factors. Their estimates for QE1 and QE2 are quite similar to those just mentioned. They also report a sizable −50 basis point effect of QE3, reflecting the very large magnitude of the asset purchases at that time. The estimated Maturity Extension Program effects are roughly half the size of the other programs. Also employing a modified affine term structure models, Hamilton and Wu (2012) used measures of asset supplies to forecast the three factors on which the term premiums depend. They put the impact of the Maturity Extension Program at −27 basis points—somewhat larger than the Ihrig, Klee, Li, Schulte, and Wei (2012) estimate, but still smaller than the effects than the large-scale asset purchases.

There are several reasons to use caution in interpreting the time series results. First, estimates of the term premium can differ a great deal across models, as illustrated in Rudebusch, Sack, and Swanson (2007). Second, the confidence intervals associated with the term premium estimates are wide. As Li, Meldrum, and Rodriguez (2017) note, it is hard to estimate the long-run average yields and the parameters characterizing the speed of mean reversion.[10] Third, the term structure models assume stable parameters, which may be unwarranted during a financial crisis with unprecedented policy tools being introduced.

What Explains the Interest Rate Declines?

There are competing explanations for what channels were most important in connecting unconventional monetary policy and falling interest rates. In late 2008 and early 2009, improvement in market functioning probably accounted for much of the sharp initial drop in yields under QE1. Gagnon, Raskin, Remache, and Sack (2011) argue this case by citing

[10] Li, Meldrum, and Rodriguez (2017) also showed that the use of professional forecasts in the Kim-Wright (2005) model ameliorates these problems.

the large spreads between mortgage backed security and Treasury yields as symptomatic of market dysfunction prevailing at the time.

But remaining somewhat unsettled is the question of the importance of the signaling channel, working through expectations of future short-term rates, and the effects of large-scale asset purchases in leading to a rebalancing of portfolios, which would have affected term premiums. Disentangling these two is inherently difficult. Further complicating matters is the fact that several early announcements of large-scale asset purchases, the ones associated with the most extreme market reactions, coincided with forward guidance statements.

Some inferences can be drawn using direct market-based measures of interest rate expectations. Gagnon, Raskin, Remache, and Sack (2011) found that there was no change in the one-year-ahead forward rate on December 16, 2008; and that the 28 basis point drop on March 18, 2009, was reversed shortly thereafter. Thus, they attributed the change in the yields to the large-scale asset purchases, rather than forward guidance. Similarly, Swanson's (2017) model attributed most of the March 18 yield decline to the large-scale asset purchase factor.

However, looking at the overall impact of QE1, Krishnamurthy and Vissing-Jorgenson (2011) ascribed a larger share of the market reaction to the signaling channel. Observing that the announcements were collectively associated with a 40-basis-point reduction in the two-year federal funds futures rate, they concluded that the signaling effect accounted for a non-negligible 20–40 basis points of the 107-basis point drop in the 10-year Treasury yield. Bauer and Rudebusch (2014) reached a similar conclusion using Eurodollar futures.

Another way to address the relative importance of signaling and the expected future short-term rate vs. portfolio balance effects from large scale asset purchases and term structure effects is to look at the results implied by an affine term structure model. Using the Kim-Wright estimates of the term premium, Bauer, and Rudebusch (2014) calculated that 22 percent of the QE1-induced reduction in the 10-year yield was attributable to signaling, with 78 percent coming from the term premium. However, the estimated impact of QE1 on conventionally estimated term premiums was very imprecise, and much larger signaling effects could not be ruled out. Their favored model (with restricted risk prices) put the contribution of the signaling effect at 36 percent (and in the 30–56 percent range), which suggests that the majority of the yield decline can be attributed to a reduction in the term premium.

An additional question relating to the transmission mechanism has to do with whether it is the *stock* of outstanding assets that affects yields, stemming from market segmentation; or the *flow* of asset purchases, which could result from transitory liquidity or market functioning effects. In an effort to address this issue, D'Amico and King (2013) studies how the purchase of a specific bond affected its price, as well as those of close substitutes. Comparing yields pre- and post-QE1, and aggregating over the relevant set of bonds, they estimated a "stock effect" yield reduction of 30 basis points. Transitory "flow effects" of bond purchases were also detectable in daily data, but of a much smaller magnitude. Significantly, this micro-level evidence does not speak to the aggregate effect of removing

duration from the market, implying that the overall impact of QE1 is likely to have been larger. On the other hand, the authors note that market segmentation was likely to have been stronger during the period of QE1, when financial markets were under a great deal of stress, and consequently that supply effects are likely to have been smaller during subsequent large-scale asset purchases.. Using methods similar to those employed by D'Amico and King (2013), Meaning and Zhu (2011) found that QE2 shifted the Treasury yield curve down by roughly 20 basis points—a smaller "bang for the buck," given that the volume of Treasuries purchased was twice that of QE1.

Unconventional Monetary Policy and Effects on Economic Outcomes

The evidence discussed so far points to a meaningful impact of unconventional monetary policy. But lowering interest rates is not an end unto itself; it matters only to the extent that it affects the decisions of financial institutions, firms, and households.

In the context of unconventional monetary policy, it is especially important to cautious about treating interest rate reductions as an end in themselves. First, in an environment of financial stress, uncertainty, and scarce investment opportunities, it is not a foregone conclusion that interest rate reductions will have the same effects on spending as at other times. Perhaps in a time of economic stress, the cost of funds is of second-order importance for potential borrowers. Second, a change in term premiums may have a smaller effect than a lowering of the expected path of future short-term interest rates. Stein (2012) argues that a risk-neutral firm might adjust its capital structure to take advantage of the lower term premium, without altering its real economic decisions. Indeed, Kiley (2014) finds, using a quantitative macro model, that term premium reductions had substantively smaller expansionary effects than reductions of expected future interest rates.

Thus, in this section we discuss evidence about the effects of unconventional monetary policies on bank lending and firm behavior, and also consider some studies that try to model the overall macroeconomic effects.

Bank Lending

Two recent papers have uncovered micro-level evidence that quantitative easing increased bank lending. Rodnyansky and Darmouni (2017) used a difference-in-difference model to study the effects of large-scale asset purchases on bank lending. They regressed loan growth on indicator variables for large-scale asset purchases, which do not vary across banks, interacted with a measure of exposure of each bank to mortgage-backed securities. They found that banks with higher initial holdings of mortgage backed securities were more likely to increase lending following QE1 and QE3, both of which (and unlike QE2 and the Maturity Extension Program) entailed significant purchases of mortgage-backed securities.

Luck and Zimmerman (2017) provide parallel findings for total loan growth. Using data on mortgage originations and small business lending data reported by banks to comply with the Home Mortgage Disclosure Act and the Community Reinvestment Act, they were able to

distinguish the policies' effects on mortgage refinancing versus commercial and industrial lending. While QE1 and QE3 both encouraged banks to extend credit, only QE3 increased commercial and industrial lending. They also exploited spatial variation in banks' holdings of mortgage backed securities to assess the effects of the large-scale asset purchase on county-level employment growth. The main finding is that counties whose banks had relatively large holdings of mortgage-backed securities tended to experience more rapid employment growth following QE3, relative to those with smaller exposures. The same was not true for QE1, however, whose effects were limited to mortgage refinancing.

Firm behavior

Using firm-level micro data, Foley-Fischer, Ramcharan, and Yu (2016) found empirical support for the hypothesis that the reduction in bond yields resulting from the Maturity Extension Program materially affected firms' financing and investment decisions. They used a difference-in-difference approach, with firms' long-term debt levels before the Maturity Extension Program as the treatment variable—the idea being that those relying more on long-term debt would have benefitted more from reductions in long-term interest rates. The identifying assumption is that firms' preference for long-term debt is exogenous, and unrelated to any factors that might have affected their response to interest rates generally, or the Maturity Extension Program specifically.

Additionally, they found that firms with a relatively heavy reliance on long-term debt experienced positive excess stock returns on September 22, 2011, the day of the announcement of the Maturity Extension Program. The program also seems to have affected firm's financing decisions. In the year following the commencement of the Maturity Extension Program, firms with high levels of long-term debt tended to issue even more of it. More importantly, a greater reliance on long-term debt was associated with larger increases in capital spending and employment following the Maturity Extension Program. The asset purchases therefore appear to have affected firms' real economic decisions, not just their capital structure.

Macroeconomic Impact

Ultimately, we care about the effect of quantitative easing on macroeconomic variables like GDP and the unemployment rate. A first step towards gauging its macroeconomic implications is to translate the decline in bond yields into an equivalent reduction in the federal funds rate. Previous studies, such as Kuttner (2001), have found that a 100 basis point surprise cut in the funds rate target results in a reduction in the 10-year yield of approximately 33 basis points. Using this as a rule of thumb, it would have taken 450 basis points of funds rate cuts to produce the 150 basis point reduction in the Treasury yield that seems to have resulted from quantitative easing.

A more rigorous approach is to use a term structure model to back out the value of the (negative) latent federal funds rate that is consistent with the observed behavior of the term structure of interest rates. Wu and Xia (2016) propose a model of the "shadow federal funds rate" by truncating from below the distribution of forward interest rates, thus introducing a nonlinearity into what would otherwise have been a linear relationship between forward rates and the underlying factors. According to their calculations

(reported at https://www.frbatlanta.org/cqer/research/shadow_rate.aspx) , the shadow federal funds rate reached a nadir of –3 percent in May 2014.

Wu and Xia then used a factor-augmented vector autoregression to assess the impact of shocks to the shadow funds rate on various measures of real activity. According to their calculations, the reduction in the shadow rate reduced the unemployment rate by a full percentage point from July 2009 to December 2013, relative to a counterfactual with no quantitative easing.

Using a very different econometric model, Engen, Laubach, and Reifschneider (2015) obtained results similar to those of Wu and Xia. Feeding the 120-basis-point reduction term premium from Ihrig, Klee, Li, Schulte, and Wei (2012) into the the Federal Reserve Board's FRB/US model, they concluded that the four quantitative easing policies combined reduced the unemployment rate by 1.2 percentage points relative to what it would have been in the absence of quantitative easing.

Yet another approach to gauging the policies' aggregate effects is through the use of dynamic stochastic general equilibrium models that incorporate some sort of financial friction. In Gertler and Karadi (2013), the friction takes the form of limited arbitrage, either between risk-free government and privately issued risky assets, or across different maturities of risk-free assets. Quantitative easing is modeled as a policy in which the central bank steps in and performs intermediation between different assets that private financial institutions are unwilling to do. Under the assumption of a zero short-term interest rate, their calibration indicates that QE1 reduced the magnitude of the GDP contraction by 3.5 percentage points (quite substantial, relative to the actual peak-to-trough contraction of 4.3 percent), with QE2 increasing GDP by 1 percent within the span of a year. Quantitative DSGE results can be sensitive to model specification, however. For example, the simulations in Chen, Cúrdia, Vasco, and Ferraro (2011) put the impact on GDP of QE3 at only 0.4 percent, with considerably more market segmentation required to obtain larger effects.

Side Effects of Unconventional Monetary Policy

The evidence summarized to this point supports the view that the Fed's unconventional policies largely achieved their purpose of reducing long-term interest rates and stimulating economic activity. Concerns have been raised about the possibility of adverse unintended consequences, such as inflation, financial instability, and international spillovers, but such outcomes seem to have been modest.

Two Non-Issues

One concern was that the vast expansion in bank reserves and the monetary base would be inflationary. A number of prominent economists went so far as to write in 2010 an open letter to Ben Bernanke predicting that QE2 would risk "currency debasement and inflation" (e21 Staff 2010). This outcome did not occur, of course.

Another concern was that the large balance sheet might complicate the process of "normalizing" monetary policy—that is, switching back to the use of the federal funds interest rate as the short-term interest rate. This fear also turns out to have been misplaced. As discussed by Ihrig, Meade and Weinbach (2015), paying interest on reserves has allowed the Fed to raise short-term interest rates, even with banks holding $2.5 trillion of excess reserves.

Risk-taking

Less easily dismissed is the concern that unconventional monetary policy encouraged excessive risk-taking by firms and financial intermediaries. For example, while acknowledging that low interest rates are intended to encourage some risk-taking, Fed chair (then governor) Jerome Powell (2017) raised the question of whether or not "low rates have encouraged excessive risk-taking through the buildup of leverage or unsustainably high asset prices."

Excessive risk-taking is especially relevant to institutions, such as insurance companies, with commitments to streams of fixed future payments (Rajan 2005). It also applies to money market mutual funds, which require an interest margin of sufficient size to cover management fees. Such institutions may feel compelled to "reach for yield," investing in riskier assets in order to hit targets for investment income.[11]

Several recent studies examining the effects of quantitative easing on financial institutions find little reason for concern over additional risk-taking. Foley-Fischer, Ramcharan and Yu (2016) found that spreads narrowed between A– rated corporate bonds and Treasury yields after the Maturity Extension Program, suggesting that insurance companies were shifting towards somewhat riskier (but still high-quality) assets. (It may also have been the case that the A– securities were perceived to have become less risky as a result of the expansionary policy.) Importantly, the effect did not extend to lower-rated bonds, which typically imposed on institutional investors a more stringent capital requirement. Thus, while some reaching-for-yield may have occurred, it certainly didn't qualify as reckless.

Focusing on banks, Kurzman, Luck, and Zimmerman (2017) found that those with higher initial holdings of mortgage-backed securities were more likely to relax lending standards following QE1 and QE3. On the face of it, this suggests riskier behavior by banks. However, observing that QE1 resulted in relatively larger gains in the value of banks laden with mortgage-backed securities, they attributed the increased lending to the improvement in the banks' capital positions. Increased liquidity of mortgage-backed securities resulting from QE3 also seems to have played a role. There is nothing to indicate that the risk-taking was excessive.

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[11] An extensive literature has examined on how low interest rates affect the risk-taking of financial institutions in contexts that do not involve quantitative easing, too rich to do justice to here (for a survey, see De Nicolò, Dell'Ariccia, and Laeven 2010).

Looking at several different types of financial institutions, Chodorow-Reich (2014) examined how large-scale asset purchases might affect risks. In an event study framework, he found that for insurance companies and bank holding companies, stock prices rose and spreads on credit default swaps (a proxy for market-perceived credit risk) fell immediately following the announcements of large-scale asset purchases. He attributed this to an improvement in the value of the assets already on the institutions' books, which lessened solvency concerns. He also examined for the money market mutual funds the relationship between fixed "structural" expenses and gross yield, which is inversely related to asset quality He detected a statistically significant tendency for high-cost funds to reach for yield, but the effect was economically small, and dissipated by 2013.

Indeed, in a number of settings, a moderate increase in risk tolerance may be beneficial. For example, an economy recovering from a financial crisis, some additional reaching for yield could be welfare-improving if other distortions have resulted in too *little* risk-taking (Chodorow-Reich 2014). In this case, increasing risk tolerance should promote lending and economic recovery.

Moreover, a shift of financial institutions towards riskier investments is not necessarily accompanied by a reduction in financial stability. Very low interest rates may have reduced institutions' risk in a manner that increased the value of legacy assets and net worth. In addition, the improvement in macroeconomic conditions brought about by the expansionary policy may have decreased the credit risk associated with many of those assets. In this environment, the additional risk-taking would be beneficial.

International Spillovers

Seven years of quantitative easing and near-zero interest rates had had far-reaching effects on other economies. The evidence in Neely (2015) and Bauer and Neely (2014) shows that the Fed's QE1 announcements significantly reduced bond yields in other developed countries, by amounts roughly half that in the United States. However, the expansionary impact of the yield reductions on other countries was offset by a depreciation of the US dollar, which fell by amounts ranging from 3.5 percent for the British pound to 7.8 percent for the euro.

But the main concerns arose as because with the near-zero or even negative interest rates in Japan, the United Kingdom, and the euro area, the comparatively high rates of interest in emerging market economies attracted very large capital inflows, much in the form of portfolio investment, which put pressure on their exchange rates to appreciate.

The influx of funds presented central banks of emerging market economies with a dilemma. They were reluctant to let their exchange rates appreciate, for fear that it would lead to excessive current account deficits. They were reluctant to limit their currencies' appreciation by allowed domestic interest rates to fall along with those of developed economies, because it would have led to monetary policy that was excessively expansionary. They were reluctant to try to limit appreciation by purchasing US dollars and holding a large amount of foreign exchange reserves, which would have had a high opportunity cost in a low interest rate environment.

A number of studies have documented how the Fed's unconventional policies affected emerging market economies. For example, using a Bayesian vector autoregression with monthly data, Bhattarai, Chatterjee, and Park (2015) confirmed that a portion of the capital flows into emerging market economies emerging market economies were attributable to quantitative easing, and that the policy led to exchange rate appreciation, reduction in bond yields, and stock market booms.

Studies using high-frequency data to assess the effects of specific large-scale asset purchases also confirm that they led to capital flows into emerging market economies, although the picture emerging from these studies is more nuanced. Using an event-study approach similar to those looking at bond yields, Bowman, Londono, and Sapriza (2015) found that QE1 reduced the yields of sovereign bond yields in emerging market economies, just as it did in the United States. Subsequent large-scale asset purchases had no distinguishable effect on yields in emerging market economies. The exchange rate index for emerging market economies showed no statistically significant response to any of the large-scale asset purchases, although some individual countries experienced large movements.

To assess the magnitude of the capital flows caused by the quantitative easing policies, Fratzscher, Lo Duca, and Straub (2017) used high-frequency data on flows into more than 16,000 equity and 8,000 bond funds. They regressed daily flows on a set of three variables capturing the Fed's policies: purchases of Treasury securities, liquidity operations, and indicators for the various announcements of large-scale asset purchases. They found that the effects varied a great deal across the different asset purchases and types of assets. For example. QE1 seems to have led to an *outflow* from emerging market economies bonds and into US equities, with roughly half of those funds returning after QE2. All three of the large-scale asset purchases were also associated with some inflows into emerging market economy equity funds. In the end, the composition of mutual fund flows into emerging market seems to have been affected more than the total volume.

The large volume of portfolio investment naturally raised concerns that the Fed's inevitable normalization of policy would lead to an abrupt outflow of capital. There is some evidence suggesting that this was the case, although the overall impact was less than feared.

Aizenman, Binici, and Hutchison (2016) provided some event-study evidence that news items about the Fed's intentions to unwind its large-scale asset purchases were somewhat disruptive to financial markets in emerging market economies. Specifically, they found that remarks by Ben Bernanke hinting at tapering led to exchange rate depreciation and a widening of spreads on credit default swaps among emerging market economies. [12] The response was neither uniform nor long-lived, however. Paradoxically, emerging market

[12] Bernanke's May 22, 2013, congressional testimony was widely blamed for precipitating the infamous "taper tantrum," in which markets reacted strongly to the news that the pace of quantitative easing might slow. Bernanke said: "If the incoming data are broadly consistent with this forecast, the Committee currently anticipates that it would be appropriate to moderate the monthly pace of purchases later this year."

economies with strong fundamentals (small current account deficits, low external debt, and larger foreign exchange rate reserves) reacted more strongly to statements hinting at future tapering than those with weak fundamentals.

Conclusions

No study of the effects of unconventional policy is definitive, and all of those surveyed in this article have their limitations. A preponderance of evidence nonetheless suggests that forward guidance and quantitative easing succeeded in lowering long-term interest rates. Studies using micro data have documented tangible effects of quantitative easing on firms and financial intermediaries. Macro models suggest that the interest rate reductions are likely to have had a meaningful impact. The adverse side effects appear to have been mild, and were dwarfed by the costs of the more protracted recession in the US that is likely to have occurred in the absence of the unconventional policies. The benefits of unconventional policy therefore are likely to have outweighed the costs.

Some questions are not entirely settled. First, the persistence of the effects on interest rates remains unclear. Second, disentangling the effects of quantitative easing from those of forward guidance is difficult. Third, the effects of these policies may have been in part a function of turbulent financial conditions, or diminished over time as the novelty wore off.

Given the uncertainties and weaknesses of the evidence, what have the past nine years taught us about the appropriate design of unconventional policies, should they be needed in the future? Six tentative lessons can be drawn from the US experience.

First, unconventional monetary policy should be conducted in a rule-like manner to the extent possible. In practice, this means clearly relating asset purchases and/or forward guidance to the Fed's objectives and forecasts. A policy articulated on a flow basis conditioned on ongoing economic developments, like QE3, is likely to be more amenable to expression in terms of a rule than one involving large, infrequent discrete adjustments to the balance sheet targets.

Second, if the research indicating that quantitative easing functions primarily through the removal of duration risk from the market is correct, policy objectives could be accomplished either by reallocating a central bank portfolio of a fixed size, or by expanding the balance sheet. Given that the purpose of quantitative easing was not to increase bank reserves, it would make sense to use portfolio reallocation as the first step in implementing quantitative easing. However, given that there have been no discernible ill effects from expanding the balance sheet (independent of any that may have resulted from very low interest rates), the unsterilized purchase of long-term bonds is a perfectly viable policy option, too.

Third, forward guidance and quantitative easing are not substitutes, as they operate through different transmission mechanisms: expectations of future interest rates for the former, the portfolio balance effect (primarily) for the latter. Thus, the two policies could be implemented independently. There could also be complementarities between them. For example, to the extent that market participants interpreted the large-scale asset purchases

as communicating the Fed's interest rate intentions, they may have reinforced the impact of forward guidance on interest rate expectations.

Fourth, a central bank that engages in large-scale asset purchases faces a large exposure if interest rates rise. This can be viewed as a positive, in the sense that the interest-rate risk could commit the Fed to a larger or more sustained monetary expansion. However, wagering central bank independence is probably best reserved for truly dire circumstances. Although it would undermine the commitment value of asset purchases, an agreement with the US Treasury that would indemnify the Fed against any losses might increase its willingness to pursue quantitative easing on a large scale.

Fifth, the appropriate choice of assets to purchase will depend on the circumstances. If asset purchases operated solely via the removal of duration risk, and if changes in Treasury yields were fully passed through to those on other debt securities, then there would be no reason to purchase any assets other than Treasuries. However, the purchase of mortgage backed securities in QE1 was appropriate as a means to improve functioning of that market. Similarly, one can conceive of circumstances that might call for central bank purchases of other types of securities, such as corporate bonds and equities. But venturing into this territory would require an amendment to the Federal Reserve Act, and would raise a number of thorny issues (far beyond the scope of this paper), such as the appropriate role of a central bank in allocating credit.

Sixth, the Fed could have two distinct policy tools: setting short-term interest rates by paying interest on excess reserves, while managing the size and composition of its balance sheet. Having two instruments at its disposal would give the Fed greater flexibility to pursue multiple policy objectives. For example, Greenwood, Hanson, and Stein (2016) argued that the ongoing provision of a large volume of short-term risk-free assets would reduce the potentially destabilizing over-reliance of the private sector on short-term funding, and thus enhance financial stability. Understanding the operation and appropriate use of balance sheet policies is an important topic for future research.

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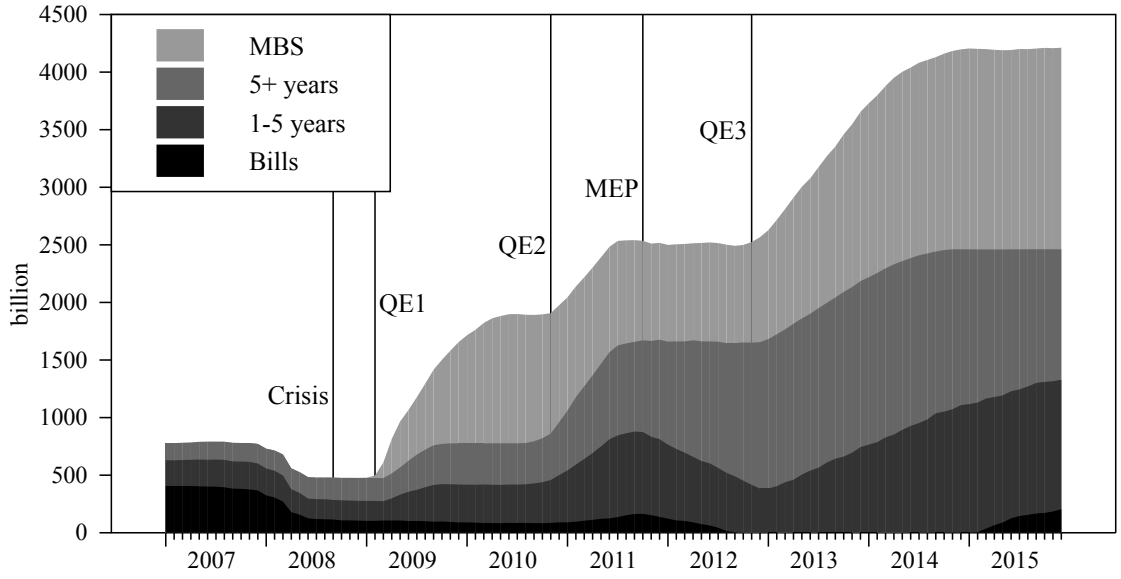
Table 1

Characteristics of the four asset purchase programs

Program	Dates	Assets	Size (billions)	Sterilized?
First LSAP (QE1)	11/2008 to 3/2009	Agency debt	$200	No
		Agency MBSs	$1,250	
		Treasuries	$300	
Second LSAP (QE2)	11/2010 to 6/2011	Longer-dated Treasuries	$600	No
MEP ("Twist")	9/2011 to 12/2012	6- to 30-year Treasuries	$667	Yes
Third LSAP (QE3)	9/2012 to 10/2014	MBSs	$40/month	No
	12/2012 to 10/2014	Longer-dated Treasuries	$45/month	

Figure 1

The composition of the Federal Reserve's System Open Market Account portfolio



Note: Excludes assets associated with temporary liquidity facilities and US Treasury floating rate notes.

Table 2

Estimated event-study interest rate effects

Study	Window (days)	Yield	QE1	QE2	MEP	QE3
Gagnon *et al*. (2011)	1	T10	-91^{***}			
		Agency	-156^{***}			
		MBS	-113^{***}			
Krishnamurthy &	2	T10	-107^{*}	-30^{***}		
Vissing-Jorgenson (2011)		Agency	-200^{***}	-29^{***}		
		MBS	-88	-13^{**}		
Ehlers (2012)	1	T10		-14	-27^{***}	
	2	T10		-40^{***}	-46^{***}	
Bauer and Neely (2014)	1	T10	-123^{**}	-23		-14

Notes: Figures are in basis points. T10 refers to the 10-year Treasury yield, MBS to yield on 15-year Agency mortgage-backed securities, and Agency to the yield on debt issued by Ginnie Mae, Fannie Mae, and/or Freddie Mac. Asterisks indicate the magnitude of the ratio of the observed event-day relative to the standard deviation of the yield changes at the indicated horizon, as reported by the authors: ***denotes ratios greater than 2.58 in absolute value (1 percent tail), **ratios greater than 1.96 (5 percent tail), and *greater than 1.69 (10 percent tail).

Table 3

Estimated effects of Quantitative Easing on 10-year term premiums

Study	QE1	QE2	MEP	QE3
Gagnon *et al*. (2011)	-38^{*}			
D'Amico *et al*. (2012)	-35	-45		
Ihrig *et al*. (2012)	-40	-40	-17	$-50^{\dagger}$
Hamilton & Wu (2012)			$-27^{\ddagger}$	

Notes: Figures are in basis points. *The smallest of the range of estimates reported. †Estimated by Engen, Laubach and Reifschneider (2015) using the Ihrig, Klee, Li, Schulte, and Wei (2012) model. ‡The reported impact of a $400 billion maturity swap, scaled up to the $667 billion size of the Maturity Extension Program.

Figure 2

Kim-Wright estimated 10-year term premium and 10-year Treasury yield