A Survey of the Empirical Literature on U.S. Unconventional Monetary Policy

Saroj Bhattarai
University of Texas at Austin
Christopher J. Neely*
Federal Reserve Bank of St. Louis

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Abstract: This paper reviews and critically evaluates the empirical literature on the effects of U.S. unconventional monetary policy on both financial markets and the real economy. In order to understand how such policies could work, we also briefly review the literature on the theory of such policies. We show that event studies provide very strong evidence that U.S. unconventional policy announcements have strongly influenced international bond yields, exchange rates, and equity prices in the desired manner. In addition, such studies indicate that such policies curtailed market perceptions of extreme events. Calibrated modeling and vector autoregressive (VAR) exercises strongly suggest that these policies significantly improved macroeconomic outcomes, raising U.S. GDP and CPI, through these changes in asset prices. Both event studies and VARs imply positive international spillovers of such policies.

Keywords: quantitative easing, event study, unconventional monetary policy, zero lower bound.

JEL Codes: G12, E34, E51, E58, E61, F31

* Corresponding author. Send correspondence to Chris Neely, Box 442, Federal Reserve Bank of St. Louis, St. Louis, MO 63166-0442; e-mail: neely@stls.frb.org; phone: 314-444-8568; fax: 314-444-8731. Saroj Bhattarai is an assistant professor of economics at University of Texas at Austin. Christopher J. Neely is an assistant vice president and economist at the Federal Reserve Bank of St. Louis. The authors are responsible for errors. The views expressed in this paper are those of the authors and do not reflect those of the Federal Reserve Bank of St. Louis or the Federal Reserve System.
1. Introduction

Extreme credit market disturbances associated with the international financial crisis prompted central banks around the world to undertake emergency lending and conventional and unconventional monetary policies in order to first stabilize the global economy and later to stimulate its growth. For example, the Federal Reserve first engaged in emergency lending to stabilize financial markets, even as it lowered the Federal funds rate target nearly to zero, purchased bonds on an unprecedented scale, and attempted to reduce expectations of future short rates with a policy of “forward guidance.” The Fed would eventually announce asset purchases that would total several trillion dollars, starting in November 2008 and continuing through the present with reinvestment. Other central banks, most notably the Bank of England, the European Central Bank and the Bank of Japan, also engaged in unconventional monetary policies.

Unconventional monetary policies are those policies that attempt to influence long-term interest rates or other asset prices through central bank communication (i.e., “forward guidance”) or asset purchases.¹ Forward guidance can take the form of either “Delphic” or “Odyssean” forward guidance (Campbell et al. (2012)), meaning that it can either predict the future or attempt to commit to a given course of future action. Asset purchase programs are commonly called quantitative easing (QE), although they should arguably be called “credit easing” (Bernanke (2012)) because their effect on long-term interest rates doesn't come from an increase in the quantity of the monetary base but rather from a combination of effects on long-term yields through liquidity, signaling and portfolio balance channels.² By providing a consistent purchaser of assets, a central bank can encourage other participants in the market and raise prices by providing liquidity. The signaling channel would reduce expected future short-term interest rates and thereby reduce the expectations component of long-term interest rates. To the extent that assets are imperfectly substitutable, the portfolio balance effect predicts that a large-scale purchase of long-term bonds can reduce long yields of both U.S. long-term yields and international substitutes through its effect on the term premia.

¹ Ait-Sahalia, Andritzky, Jobst, Nowak and Tamirisa (2012) construct a database of early policy interventions — i.e., fiscal policy, emergency lending, monetary policy — for the U.S., UK, euro area and Japan for the period June 1, 2007 to March 31, 2009 and use an event study to examine how financial spreads and stress indicators respond to the policies. The paper concludes that bank recapitalization and interest rate cuts were the most effective policies in reducing stress.

² Policies that increase the monetary base, including asset purchases and lending programs are commonly called QE. Credit easing programs are a special case of QE if they also increase the monetary base.

Because asset purchases were sometimes announced contemporaneously with forward guidance, particularly during the QE1 episode, many studies of unconventional policy could not distinguish between the effects of forward guidance and asset purchases. Thus, the literature on unconventional policies often conflates the effects of asset purchases with forward guidance.
These unconventional monetary policies that involve influencing long-term interest rates through asset purchases or forward guidance can be distinguished from other unconventional central bank activities that are more closely related to the lender-of-last-resort role. For example, the creation of the Maiden Lane corporations by the Federal Reserve in order to hold assets of failed financial institutions is certainly unconventional, but the Federal Reserve created Maiden Lane LLC I, II and III to hold risky assets from Bear Sterns and AIG, which were more closely related to the lender-of-last-resort role than the traditional monetary policy role.\(^3\)

For decades, the Federal Open Market Committee (FOMC) used open market operations to guide the main instrument of monetary policy in the United States: the Federal funds rate, an overnight interbank lending rate. In August 2007, the Federal funds target stood at 5.25 percent. Over the next 16 months, the FOMC reduced the federal funds target repeatedly, until it reached the 0 to 25 basis point range on December 16, 2008. With short rates approaching the zero lower bound (ZLB) in late 2008, the Federal Reserve began to pursue unconventional monetary policies to stimulate the economy, including forward guidance about future short rates, MBS and Treasury purchases called large-scale-asset purchases (LSAP) or quantitative easing (QE) and the maturity extension program (MEP).\(^4\) The direct target of such unconventional policies was to reduce long-term interest rates in order to support credit markets—especially for housing—in order to ultimately stimulate real economic activity.\(^5\)

Other central banks also pursued unconventional policies. Fawley and Neely (2013) detail the quantitative easing programs of four major central banks: the Federal Reserve, Bank of England, European Central Bank, and Bank of Japan during the recent financial crisis and recovery. All of these central banks initially pursued unconventional asset purchases to alleviate financial market distress, but their goals soon broadened to include achieving inflation targets, stimulating the real economy, and containing the European sovereign debt crisis. The nature of respective financial systems strongly influenced the unconventional policy methods. That is, the European Central Bank and Bank of Japan focused on direct lending to banks while the Federal Reserve and the Bank of England purchased bonds to expand their respective monetary bases.

In the years since the Fed began these policies, a sizable and growing literature has empirically studied their effects. The goal of this paper is to summarize and critically evaluate that literature in order to infer the effectiveness of unconventional policy. Differences in

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\(^3\) The Federal Reserve also conducts annual Comprehensive Capital Analysis and Review (CCAR) of large bank holding companies. The unconventional monetary policy measures should also be distinguished from the numerous programs to support the real economy through the financial system. On September 7, 2008, the Federal Housing Finance Agency (FHFA) placed Fannie Mae and Freddie Mac into conservatorship. In October 2008, the FDIC established the Temporary Liquidity Guarantee Program (TLGP) to facilitate interbank lending. In early 2009, The US Treasury, created the “Making Home Affordable” support program to help homeowners avoid foreclosure.

\(^4\) Arguably, the bond purchases should have been called credit easing (CE), as they were specifically designed to improve credit conditions in bond markets.

\(^5\) Some central banks, such as the European Central Bank and the Reserve Bank of Australia, never reduced short-term rates to the zero lower bound.
unconventional policy between central banks make it difficult to generalize across their effects (Fawley and Neely (2013)). Therefore, this paper focuses specifically on the empirical literature on the effects of U.S. unconventional monetary policy on both financial markets and the real economy. Although this paper focuses on empirical evaluations of unconventional policy, one must understand how such policy could work in order to assess its effects. We thus also review the literature on the theory of such policies, albeit in a cursory fashion, to help interpret the empirical results.

The use of event studies on financial asset prices produce the strongest results from this literature. Fortunately, the novelty of the first QE program (QE1) allowed researchers to plausibly argue that all important changes in expectations about it occurred in a small set of events related to FOMC communications. This allowed those researchers to estimate the effect of a given quantity of asset purchases from the reactions to those events. Event studies imply that a surprise announcement of a one trillion USD purchase of long-term bonds reduced 10-year U.S. Treasury yields and low-grade corporates by about 30 to 50 basis points while MBS yields declined by 66 basis points and mortgage rates fell further still (Krishnamurthy and Vissing-Jorgensen (2011)), Hancock and Passmore (2011)). Foreign sovereign 10-year yields likewise declined by 10 to 25 basis points while the $1 trillion purchase reduced the value of the USD by 3.5 to 6 percent and raised stock prices by perhaps 1-1.5 percent (Neely (2015), Kiley (2014)). Unconventional policy announcements reduced also near-term option-implied tail risk—the risk-neutral implied probability of extreme events—in equity and interest rate markets (Hattori, Schrimpf and Sushko (2016)), suggesting that unconventional announcements were perceived to have a stabilizing and stimulatory effect. Finally, the great majority of the effect of unconventional policy probably occurs with announcements that change market expectations, transactions themselves do have local, microstructural effects that change yields on the specific issues purchased by a few basis points (D'Amico and King (2013)).

The literature on the macro effects of QE has also developed, with models suggesting a variety of mechanisms by which QE can affect the macro economy. The impact of such mechanisms have been simulated by calibrated DSGE models while other empirical researchers have used a variety of vector autoregressive (VAR) models to estimate the macro impact of unconventional policies. These papers suggest that unconventional policy has had some significant impact on macro variables, for example, Bhattarai, Chatterjee, and Park (2015) find that a one standard deviation shock to assets purchases—i.e., 40 billion dollars—reduces 10-year Treasury yields by 10 bp on impact and increases industrial production and consumer prices by 0.4% and 0.1%, respectively, at a horizon of 10 months. Weale and Wiedelak (2016) similarly used VAR analysis to determine that an asset purchase of 1% of GDP raises GDP and CPI by 0.58% and 0.62%, respectively. Their conditional forecasting analysis implies that QE1 raised GDP and CPI by about 2 percentage points at its peak, while QE2 raised GDP and the CPI by about 6 percentage points.
Section 2 briefly reviews how unconventional monetary might affect asset prices and the larger economy, while section 3 describes the U.S. unconventional monetary policies themselves. Sections 4 and 5 describe the empirical literature on U.S. unconventional policy effects on financial markets and the larger macroeconomy, respectively.

2. Models of Unconventional Policy

Unconventional policy effects on asset prices: How should one expect unconventional monetary policy to affect asset prices and the macroeconomy? Monetary policy potentially works through a variety of channels, but mainly through asset prices. Therefore, any assessment of the effectiveness of monetary policy starts with the ability of monetary policy to systematically affect interest rates and perhaps other asset prices. Unconventional policy has therefore focused on purchasing long-bonds and shaping expectations of future short-term interest rates in order to influence long yields.

Long yields can be decomposed into two components: the expected average future short-term rate and the residual, which is denoted the “term premium.” The expected short rate is a function of expected inflation, expected real activity and some judgement about the preferences of the central bank. The term premium, which is usually positive, can, in principle, be either positive or negative, and varies over time and across various bond types.

Potentially, several different risk factors can affect the term premium and different bonds have different exposures to these factors. Table 1 summarizes how yields of different bonds are subject to various risks. The prices of all long-term bonds fluctuate with long yields; this risk is called “duration risk.” Corporate and other privately issued bonds are also subject to default risk. In contrast, Treasury and Agency bonds are considered nearly riskless and so do not have appreciable default risk. The term premium can also include a “liquidity premium” that reflects the expected ease of trading in the given bond. On-the-run Treasuries—Treasuries that have most recently been issued — typically trade at a premium to similar off-the-run Treasuries. Bond prices can also reflect a “local scarcity” term that reflects a premium for particular bond issues. The local scarcity channel implies that a change in the supply of bonds with some specific characteristics, i.e., sector and maturity, can differentially influence the yields of those bonds and bonds with similar but not identical characteristics.

Finally, the term premium can also include a “safety premium” that applies only to long-term assets with very low default risk, such as Treasury and Agency bonds, that offer an almost sure

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6 The U.S. Treasury explicitly guaranteed agency liabilities in September 2008 and Treasury officials have since reiterated this promise (e.g., Barr (2010)).

7 Central bank asset purchases through the “liquidity channel” provide a consistent purchaser of assets, which encourages other participants in the market and raise prices by providing liquidity. Because markets were truly liquidity constrained only very early in the crisis, it is likely that the liquidity channel could only have been a significantly factor in the very first months.
nominal return. There is evidence of specific client demand for such assets, which makes the relationship between price and default risk of bonds very steep at low default rates, and which then flattens as the supply of safe assets such as Treasuries increases. Thus, this clientele demand-driven effect can differentially affect term premia of bonds safer than say, Baa bonds. Moreover, through this channel, the total supply of Treasuries, which are considered safe, can affect the interest rate spread between say, Aaa and Baa bonds.

Mortgage-backed securities differ from Treasury and corporate bonds in that they are subject to "prepayment risk", meaning that the mortgage holders can prepay their mortgages without penalty, and will do so if long rates decline. In other words, the mortgage has an implicit call option on the bond embedded in it. Borrowers often choose to refinance and pay off their existing mortgage when long-term interest rates fall (i.e., when bond prices rise). Mortgage interest rates must be higher than they otherwise would, to reflect the value of the call option for the borrower. Options reflect the expected volatility of the underlying asset (i.e., long rates) but they may also contain an additional risk premium associated with being exposed to changes in that volatility. This prepayment risk precludes the "safety premium" from applying to MBS yields.

If unconventional policy influences long yields, it will generally also affect the prices (expected returns) to other assets, such as stock prices, exchange rates, foreign yields and commodities. For example, to the extent that unconventional policy changes discount rates and economic activity, it will change stock prices, which are the expected discounted stream of future cash flow. Likewise, foreign bonds are imperfect substitutes for domestic bonds. Any change in the yields of U.S. bonds will imply a change in foreign yields so that all assets are willingly held in equilibrium.

Unconventional policy effects in macroeconomic models: In order to model the plausible macroeconomic effects of LSAPs and determine whether these effects improve welfare, theoretical models must provide some mechanism to affect either the expected future interest rate or the risk premium associated with various elements of the term premium. To do that, they introduce various financial frictions or assume that the government cannot commit to a fully credible path of future policy. Such mechanisms are needed in order to break the neutrality of such open market operations, which was first pointed out in a classic paper by Wallace (1981). In Wallace’s (1981) model, the size and/or composition of the central bank’s balance sheet, or, equivalently, the supply of assets in the hands of the public, has no effect on real or financial variables. Therefore, to model the effects of LSAPs, DSGE models must introduce frictions.

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8 Later in the paper we discuss theoretical models that provide mechanisms that make assets of different maturities or nominal denominations imperfectly substitutable.
9 Bowdler and Radia (2012) usefully discuss the methods and channels of unconventional monetary policy. The authors contrast a monetarist view of QE with a conventional New Keynesian view in which QE—the exchange of
The literature has introduced several types of frictions, including heterogeneity in asset preferences, various forms of asset market segmentation, and other limits to arbitrage. Heterogeneity in preferences in assets and market segmentation make assets imperfect substitutes. With imperfect substitutability, LSAPs alters relative supplies and reduce risk/term premium through a portfolio balance channel. That is, LSAP-induced changes in relative supply of assets can then change equilibrium asset prices and macroeconomic quantities.

Alternatively, some papers assume that while typically the private sector is more efficient than the government in financial intermediation, the government can circumvent limits to arbitrage faced by the private sector. That is, the government can avoid binding leverage constraints because it can raise funds elastically by issuing debt, unlike the private sector. In such models, LSAPs that function as direct lending by the government to the non-financial sector can improve the functioning of credit markets and help achieve the desired level of financial intermediation.

A third set of models finds a role for LSAPs if governments cannot credibly commit to the future path of policy. That is, by changing the size and composition of the central bank balance sheet and leading to mismatches in duration of assets compared to liabilities, LSAPs can alter expectations of the future policy rate as the central bank seeks to avoid deleterious revaluation effects on its balance sheet. That is, LSAPs provide a signal to the private sector about the future path of the short-term interest rate. This mechanism can arise even in a model with frictionless financial markets.

Importantly, although LSAPs can theoretically induce portfolio balance, improved financial intermediation, and signaling effects even during normal times at positive interest rates, they are particularly useful at the ZLB, beyond which the short-term interest rate, the conventional monetary policy instrument, cannot be lowered further to stabilize the economy. These models thus provide a natural justification for large-scale asset purchase (LSAP) policies by the Federal Reserve, which it undertook in a ZLB scenario only.\(^\text{10}\)

Researchers have used these competing assumptions to construct models of financial markets and the macroeconomy. Vayanos and Vila (2009) and Greenwood and Vayanos (2014) introduced and used the first set of features — preferred habitat preferences — to analyze the term structure of interest rates and bond returns. These models assume some financial market participants prefer bonds of certain maturities, perhaps because of legal restrictions or the desire to hedge asset positions of similar characteristics. This preference makes bonds of different maturities imperfect substitutes. Hamilton and Wu (2012) derive a no-arbitrage affine term structure model (TSM) in

\(^\text{short-term liquid assets for long-term illiquid assets}——\text{is irrelevant and the only way to reduce real rates is to increase inflation expectations.}\)

\(^\text{Unconventional purchases of assets are most commonly called “quantitative easing” (QE) in the financial press but “large-scale asset purchases” (LSAP) by the Federal Reserve.}\)
this preferred-habitat framework and use it to assess the effectiveness of LSAPs that reduce the supply of long-term government bonds in the hands of the public.

Similar preferred habitat preferences among investors have inspired DSGE modeling: Chen, Curdia, and Ferrero (2012) develop a preferred-habitat DSGE model from the simpler model in Andres, Lopez-Salido, and Nelson (2004). In particular, some fraction of households in the model trade in imperfectly substitutable short- and long-term government bonds while paying transaction costs; the remaining fraction trade only in long-term government bonds and do not pay transaction costs. They combine this exogenous market segmentation feature in a standard sticky-price DSGE model with a ZLB on the short-term interest rate. These features allow the stock of long-term government bonds to produce a risk/term premium that contributes to long-term yields. Therefore, a central bank purchase of long-term government bonds from the public can then reduce long-term yields and thereby affect the macroeconomy. The authors use this model to study the effects of LSAP II, which involved purchases of long-term Treasury debt by the Federal Reserve. This can be considered an analysis of the portfolio balance effects of LSAPs.

The second group of models eschews preferred habitats for its investors and instead derives a role for unconventional policy from the agency problem between households and financial intermediaries, as financial intermediaries can potentially abscond with funds. Gertler and Karadi (2011) and Gertler and Kiyotaki (2010), and Gertler and Karadi (2013) model frictions in financial intermediation and private sector limits to arbitrage. In these models, financial intermediaries borrow from households and lend it to goods-producing firms to purchase capital. Optimal contracting between households and financial intermediaries then leads to an endogenous constraint on leverage ratios. When financial intermediaries face a binding balance sheet constraint, any shock that reduces the net worth of the financial intermediaries causes the intermediaries to reduce lending to goods-producing firms, which reduces investment and output. Such a transmission mechanism is referred to as a financial accelerator.

The financial accelerator mechanism provides a role for QE policies to mitigate the adverse outcomes of the financial shock, particularly when the ZLB on the short-term interest rates binds. The central bank, which is not subject to the leverage ratio constraint, can elastically raise funds by issuing riskless debt and effectively fund lending through QE. While the central bank is less efficient in the model than private intermediaries, the lack of a leverage constraint on the central bank means that it can improve welfare in a financial crisis by directly lending to non-financial firms.11

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11 Curdia and Woodford (2011) also extend the standard New Keynesian model to include a central bank with a balance sheet. In this model, quantitative easing still has no effect. There is, however, a role for targeted central bank...
In the third set of models, LSAPs can work even without financial frictions. The key departure from traditional models is that the central bank cannot credibly commit, either to a fully optimal state-contingent path for policy or to a simple policy rule. Then, LSAPs act as a commitment device to make the public believe that central banks will not raise interest rates too soon. Bhatarai, Eggertsson, and Gafarov (2015) present a model, without financial frictions, where LSAPs have macroeconomic effects because they affect the public’s expectations of the future path of the short-term interest rate. Although the government/central bank in the model cannot fully credibly promise a future path of the policy (instrument), it can change the size and/or composition of the central bank balance sheet to affect both long-term yields and macroeconomic quantities through a signaling channel.

In the model, the central bank’s balance sheet features a duration mismatch: the central bank holds long-term government bonds but its liabilities are short-term interest-bearing reserves. As the economy exits from the ZLB in the model, raising short-term interest rates reduces central bank remittances to the Treasury, as it affects interest payments on its short-term liabilities more strongly than interest received on its long-term assets. If one (plausibly) assumes that central bankers dislike the political consequences of rapidly reducing remittances to the Treasury, then the central bank has incentives to delay increases in short-term rates. The central bank’s incentives to slow interest rate increases rise with the size of the balance sheet (holding the duration mismatch constant) and the extent of duration mismatch (holding the size of the balance sheet constant). Thus, the authors argue that LSAPs, which increased the size of the Fed’s balance sheet and strengthened duration mismatch, can signal that the central bank will keep interest rates lower than it would otherwise. This then affects both long-term yields and output in the model.

3. The Federal Reserve’s Unconventional Policies

As of August 2016, the Federal Reserve has announced three quantitative easing (QE) programs and a maturity extension program that have collectively purchased over $4 trillion in medium and long-term securities—Treasuries and MBS—using high-powered money creation or the sale of short-term assets to fund those purchases.

The Fed’s QE1 programs. The Federal Reserve began its asset purchase programs on November 25, 2008, with a press release that announced plans to purchase $100 billion in asset purchases when frictions prevent private agents from fully utilizing financial markets. Such central bank purchases may not necessarily improve welfare, however.

Williamson (2016) presents a micro-founded monetary model where collateral is scarce in the economy and long-term government debt is a worse collateral than short-term government debt. In this environment, QE, where the central bank swaps long-term government debt with short-term, is desirable as it relaxes collateral constraints. Moreover, such policy decreases long-term nominal yields. But somewhat differently from a New Keynesian model and from conventional thinking on empirical effects of QE, real yields actually increase and inflation decreases.
government-sponsored enterprise (GSE) debt and $500 billion in mortgage-backed securities (MBS) issued by those GSEs (Table 2). The Fed followed up on March 18, 2009, when it announced additional purchases of $100 billion in GSE debt, $750 billion in MBS, and $300 billion in long-term Treasury securities. The March 18th announcement was not expected and produced very large effects in asset markets. These $1.725 trillion in purchases roughly tripled the U.S. monetary base, substantially increasing excess reserves held at the Fed. Moreover, they were directly linked to support the housing market. Housing GSE debt and MBS accounted for more than 80 percent of the QE1 purchases.

**The Fed pursues QE2.** By the second half of 2010, financial markets had regained orderly operation but real activity remained sluggish. Many analysts were still concerned about a disinflationary trend as U.S. consumer price index inflation dipped toward 1 percent. To counter this trend, the Fed announced, on August 10, 2010, that it would maintain the size of its balance sheet by reinvesting the principal payments on previous asset assets into Treasuries. Chairman Bernanke followed up on August 27, 2010 by reminding markets that the Fed could purchase more assets, should conditions warrant (Table 2). The September 21, 2010, FOMC statement reiterated concerns about low inflation and paved way for the widely expected November 3, 2010 FOMC announcement of a purchase of an additional $600 billion in U.S. Treasuries to “promote a stronger pace of economic recovery and to help ensure that inflation, over time, is at levels consistent with its mandate.” The FOMC thus designed this program, “QE2,” to lower long-term real interest rates and boost the inflation rate to levels deemed more consistent with the Fed’s price-stability mandate from Congress.

**The Fed twists again.** In response to renewed fears of recession and a spike in the financial stress index in the summer of 2011, on September 21, 2011 the FOMC announced a new type of program to extend the maturities of its Treasury portfolio, the Maturity Extension Program (MEP) and Reinvestment Policy (Table 2). In addition, the FOMC also announced it would begin reinvesting maturing MBS and agency debt in MBS rather than Treasuries. Because the MEP was intended to reduce long-term interest rates relative to short-term interest rates, thus “twisting” the yield curve, the program was nicknamed “Operation Twist.” In this program, the Fed sold $400 billion in short-term assets while purchasing $400 billion in long-term assets. Operation Twist did not expand the U.S. monetary base because short-term asset sales, rather than money creation, funded the long-term asset purchases.\(^\text{12}\)

**The Fed extends Operation Twist and introduces QE3.** During the spring and summer of 2012, U.S. nonfarm payrolls grew significantly slower than expected and markets began to speculate that the Fed would ease further. On June 20, 2012, the FOMC extended the MEP,\(^\text{12}\)

\(^{12}\) There is precedent for the MEP. Specifically, the Federal Reserve attempted to lower the long end of the yield curve in a previous Operation Twist in the early 1960s. Modigliani and Sutch (1966) found that this earlier attempt to bring down long rates was not successful, probably because new Treasury issuance offset the modestly sized purchases (Blinder, 2000). Swanson (2011) applies modern event study methods to “Operation Twist,” finding it to have moderate effects on Treasury yields but much smaller effects on corporate yields.
which had originally been scheduled to end in June. The additional purchases (and sales) continued at the previous pace and were expected to total $267 billion.

Labor markets remained sluggish despite this effort. Chairman Bernanke acknowledged that “the stagnation of the labor market in particular is a grave concern” and that “the Federal Reserve will provide additional policy accommodation as needed” in his annual Jackson Hole speech. Against this backdrop of expected accommodation as needed, the FOMC announced a third round of quantitative easing, or QE3, on September 13, 2012. QE3, however, differed from previous programs in that it committed to a pace of purchases rather than a given quantity. The Fed would purchase $40 billion MBS per month as long as “the outlook for the labor market does not improve substantially…in a context of price stability.” The conditional structure of the program is consistent with Bullard’s (2010) argument that “quantitative policy should be state contingent; that is, it should adjust to incoming information on the state of the economy.”

The FOMC announced on December 12, 2012 that long-term Treasury purchases under the MEP would continue at the pace of $45 billion/month, but such purchases would no longer be offset (i.e., sterilized) through sales of short-term Treasuries. Hence, future purchases would expand the monetary base.

Figures 1a and 1b illustrate the historical evolution of the assets and liabilities of the Federal Reserve during the unconventional policy period. The Federal Reserve’s balance sheet clearly expanded rapidly during the unconventional policy period, compared to the pre-ZLB period. In addition, the composition of Fed assets changed dramatically as the Federal Reserve bought large amounts of long-term Treasury and Agency bonds and MBSs. The counterpart was the large expansion of Federal Reserve liabilities, in the form of reserves, on which the Federal Reserve pays interest. The non-interest bearing liabilities, cash, expanded much less. Almost all of the reserves are excess, that is, held in addition to required reserves to back deposits. Figures 1a and 1b also illustrate how while most unconventional policy programs expanded the monetary base, the MEP program did not, as long-term treasury purchases were financed by the sale of short-term treasuries.


Methodologies: An efficient, forward-looking financial market should impound information about asset prices into those prices as soon as it becomes available. In the context of unconventional monetary policy, the forward-looking nature of financial markets means that researchers must examine the effects of announcements of policy changes on financial markets rather than wait for responses to transactions. The speed with which financial markets react to new information depends on whether the news is expected, the complexity of the news and the amount of heterogeneity in how the news is interpreted. For well understood, simple announcements, such as scheduled macro news releases, asset prices can generally react in
seconds or perhaps a few minutes. Unconventional monetary policy announcements are much more complex and sometimes produced reactions that appeared to last for hours.

Moreover, because financial markets adjust rapidly to new information, the asset price reaction to a policy over a course of minutes or hours or days should approximate the long-term reaction of the asset price to preclude an implausible profit opportunity in financial markets. Therefore, the efficient markets hypothesis implies that the short-term impact of some announcement is also expected to be approximately its long-term impact.

Because asset prices should react fairly quickly to news about unconventional policy and because this initial reaction is expected to be close to the long-term impact, researchers have primarily evaluated the effects of unconventional policy on asset prices through the use of “event studies.” Event studies examine asset prices in a narrow window around some incident that should influence them in order to determine the effect of that incident on the asset prices. Event studies are extremely useful for examining the impact of events on financial asset prices because financial asset markets are both forward-looking and adjust rapidly to new information.

The forward-looking nature of financial markets also creates challenges for event studies in that such markets should react only to new information and not to the expected component of an announcement. Therefore, in a standard event-study, researchers regress asset returns on some measure of the surprise component in an announcement. That is, they estimate regression of the form

\[ r_t = a + b \text{ surprise}_t + e_t, \]  

where \( r_t \) is the asset’s return. In an event study of the effect of conventional monetary policy on asset prices, the surprise would be the unexpected change in the fed funds target implied by the federal funds futures prices that occurred during an FOMC meeting. Similarly, in event studies of macro announcements, the surprise would be the unexpected component of the announced macro variable. Including the whole announcement number (expected component + surprise) in the regression will bias the coefficient toward zero. The coefficient would represent the effect of a one-unit surprise on the asset return.

Event studies generally must assume that one can identify and measure the relevant monetary shocks, that the immediate reaction to monetary announcements is the long-run effect on financial markets, and that other news has negligible effects during the event window.

In a study of unconventional monetary policy, one would ideally like to know the per-dollar effect of asset purchases. That is, one would like to measure how much a given announcement changed the market’s expectation of future purchases, i.e., the surprise. Unfortunately,
econometricians and financial markets lack reliable estimates of the expected future path of the policy instruments, that is, of the quantity of asset purchases.\textsuperscript{13}

One can, however, use some measure of the surprise change in interest rates — either the change in long yields or the change in the first principal components of the yield curve — that follows an unconventional announcement.\textsuperscript{14}

$$ r_t = a + b \Delta yields_t + e_t \tag{2} $$

Such a regression, however, can only describe the reaction of other asset prices to a given change in long yields, or perhaps more accurately, covariance of asset returns around unconventional shocks. Such a regression cannot estimate the per-dollar impact of an unconventional program.

Some researchers have dispensed with an effort to find a surprise variable and have instead regressed asset returns on indicator variables for policy announcements, sometimes separating positive from negative changes in purchase expectations.

$$ r_t = a + b_1 I_t(easing \text{ announcement}_t) + b_2 I_t(tightening \text{ announcement}_t) + e_t \tag{3} $$

Unfortunately, the coefficients in such a regression represent the “average” impact of the given set of announcements, which has no particular economic meaning because it depends on the quantity of events included in the event set and how often expectations shifted back and forth.

There is, however, a plausible way in which one could use event studies to estimate the per-dollar impact of an unconventional policy program. Under the assumption of rational expectations, if one could identify some finite set of events on which all the changes in expectations about a program occurred, then one could use the sum of the asset price changes to estimate the per-dollar impact of the program in an unbiased fashion. This would be true even if some or most of the events were substantially anticipated from previous actions or if they had conflicting effects on yields.

A potential pitfall with this strategy of summing reactions over an event set is that one must choose an event set that reflects all changes in expectations. Such a choice inevitably means that researchers must trade off bias vs. efficiency. Smaller event sets may miss important changes in policy expectations and thus be biased. In contrast, large event sets may contain irrelevant events.

\textsuperscript{13} Perhaps the best way to quantify expectations of purchases is with the New York Fed’s Survey of Primary Dealers (SPD), conducted prior to every FOMC meeting about expectations of monetary policy and the economic outlook (see Correa-Golay, Friedman, and McMorrow (2013)). Starting in 2011, the SPD began to ask questions about forward guidance and, later, about the monthly pace of asset purchases and expectations of the size of the System Open Market Account (SOMA), i.e., the Fed’s balance sheet. The use of such expectations can help gauge the unexpected component of policy and therefore the effect of a given policy change on financial markets. The SPD can also help policymakers learn of market participant’s view of the efficacy of different strategies — e.g., buying Treasuries vs. MBS — for achieving their goals.

\textsuperscript{14} During the period of 2008-2011, the first principal component of the change in the yield curve around unconventional announcements is very highly correlated with the change in long yields over the same events.
and thus produce inefficient estimates of the effect of the whole program. To allow the reader to see uncertainty associated with event sets, researchers sometimes report results from multiple event sets.

Consider an example: A central bank institutes a bond buying program in which each $100 billion purchase of long bonds reduces long yields by 5 basis points. Suppose that three events change market expectations.

1. Monday: The Governor publicly suggests future long-bond buying is possible. Market expectations of long-bond purchases rise from $0 to $100 billion and long yields fall by 5 basis points.
2. Tuesday: The central bank officially announces a $500 billion purchase program, which raises expectations of total purchases from $100 billion to $500 billion and reduces yields by an additional 20 basis points for a total cumulative drop of 25 basis points.
3. Wednesday: The central bank announces that it will reduce the size of the program to $400 billion, expectations of the total purchase fall to a $400 billion purchase and yields rise by 5 basis points. The sum of the yield changes is now 20 basis points.

The three changes in expectations were unequal and the second change was partially anticipated but the sum of changes over all three events correctly implies the final size of the program: $400 billion or 20 basis points in yield terms.

Because QE1 was a novel program and markets were unfamiliar with the Fed’s reaction function for unconventional policy, it is plausible that FOMC communications produced all important changes in expectations about QE1. Several researchers exploited this assumption to estimate the impact of QE1 from the sum of FOMC events, i.e., speeches, FOMC statements, etc. — on asset prices. For later rounds of unconventional policy, however, it is likely that market expectations changed more frequently in response to all sorts of news and thus it is less plausible that one could estimate the per-dollar or total impact of later QE programs.

Because event studies require these fairly strong assumptions, researchers have sought to examine whether other methods provide similar inference to those implied by event study results. In particular, researchers have sought to use regression methods with lower frequency (i.e., monthly or quarterly) data to examine the robustness of event study conclusions.

Methods to assess channels of monetary policy: Variations on event studies can answer the very important question of the channels by which unconventional policies have their effects. Recall that yields on long-term bonds can be decomposed (by definition) into the expected average future short rate and the term premium. The expected future short rate is determined by expectations of inflation, real economic activity and the preferences of the central bank. The term premium, as discussed above, depends on compensation for duration risk, default risk, prepayment risk, liquidity, safety, and local scarcity.
By examining asset prices that have differential exposure to various types of risk around policy announcements, one can assess how the policy announcements affect the compensation for a particular type of risk. For example, the change in the difference between long-term Treasuries and long-term corporates probably primarily reflects an assessment of how the policy announcement is perceived to affect default risk (with some possible additional differences due to safety and liquidity effects). Likewise, the difference between long-term Treasuries and Agency MBS probably primarily reflects an assessment of how the policy announcement affects prepayment risk (with some possible additional differences due to safety and liquidity effects). Moreover, the difference between long-term Treasuries and long-term Agencies probably primarily reflects an assessment of how the policy announcement affects the liquidity premium. Table 1 presents the risks to which different types of bonds are exposed and can be used to assess these effects by appropriately taking the “difference” of one column (asset) with another column (asset), and thereby isolating the effects through one particular channel/risk. This can be thought to be analogous to a “difference-in-difference” type strategy.

The broadest distinction between channels is that between “signaling” and “portfolio balance” effects. Signaling directly affects the expected average overnight yield while portfolio balance effects affect the term premium, i.e., the excess of the long yield over the expected overnight yield over the life of the bond. Therefore, to assess the relative importance of these two effects from an announcement, one needs both the change in the yield and some estimate of the change in the expected average overnight rate. One can use several methods to decompose yields in this manner.

The swap rate is a useful and direct measure for decomposition of the long yield into an expected path of short rates and a residual (the term premium). A swap rate is the fixed interest rate that market participants are willing to exchange for the payments on a floating interest rate loan. If market participants were risk neutral, it would be the expectation of the average short-term interest rate over the horizon of the interest rate swap. Therefore, changes in the swap rate at the time of an announcement can be interpreted as reflecting the signaling effect of the announcement.15

Alternatively, one can construct a TSM to decompose long yield changes into changes in the term premium and changes in expected short rates in order to shed light on the signaling and portfolio balance channels. A TSM is simply a time series model of yields that precludes arbitrage. An estimated TSM predicts the future path for all yields at each point in time. One can estimate a TSM and then examine how the predicted future path for yields changes at the point

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15 Joyce et al. (2011) conduct an event study on swap rates to argue that U.K. bond purchases were effective at least partially through the PB channel.

One might think that changes in federal funds futures prices over various horizons might allow one to estimate changes in expected future short rates. Krishnamurthy and Vissing-Jorgensen (2011), for example, looked at 3,6,12, and 24-month futures and tried to infer the importance of the signaling channel for QE1 and QE2 announcement dates. (Table 2 in their paper). This can be a problematic method, however as the federal funds futures market only has active trading at a horizon of 3 to 6 months, even in the best of circumstances.
of an unconventional policy announcement. Such changes can imply estimates of the change in the expected future path of short rates, as well as the change in the term premium, which is the long yield less the average future short rate. Of course, such calculations assume that the policy announcement does not change the parameters or structure of the TSM.

**U.S. Treasury, housing and corporate bonds:** The earliest and perhaps most important event study was Gagnon et al.’s (2011a,b) research that found that the first Federal Reserve large-scale asset purchase (LSAP) announcements in 2008-2009 substantially reduced U.S. long-term yields (see also Kohn, 2009; Meyer and Bomfim, 2010, Krishnamurthy and Vissing-Jorgensen (2011)).

As discussed previously, the novelty of QE1 set it apart from later unconventional policy programs and gave Gagnon et al. (2011a,b) a unique opportunity to study the effect of each dollar of asset purchases because one could plausibly define a set of events that contains all important changes in expectations about QE. To study the effect of the first round of QE, Gagnon et al.’s (2011a,b) examined the impact of 23 events associated with monetary policy from November 25, 2008 to February 17, 2010, on a number of domestic bond yields, including the 2-year and 10-Year U.S. Treasuries, the 10-year Agency, Agency MBS, the 10-year term premium, calculated from the Kim-Wright (2005) TSM, the 10-year swap rate, and the Baa corporate bond index. They denoted this event set the “baseline event set.” The authors also examine the impact of a larger set of announcements, denoted the “baseline + all FOMC event set.” The purpose of considering 2 event sets was to be able to study the robustness of conclusions to the size of the event set.

Table 3, which is reproduced from Gagnon et al.’s (2011b), shows that both event sets imply that there were very substantial yield (or premia) changes during the set of event days on which there were unconventional monetary policy announcements. In particular, although the 2-year Treasury rate fell by only 34 basis points over the baseline event set, the 10-year Treasury yield fell by 91 basis points over the baseline event set but only 55 basis points over the “all event” set. One interpretation of that disparity is that expectations of further QE were reduced during FOMC events in the “all event” set that were not also in the baseline set.

The 10-year Agency bonds and 10-year Agency-backed MBS fell by even more than the Treasury yield — 156 and 113 basis points over the baseline events, respectively — suggesting that the unconventional policy announcements reduced not just the riskless 10-year yields but also risk premia, such as default risk and prepayment risk.

The fall in the 10-year swap rate indicates that the expected average overnight interest rate declined in both the baseline (101 b.p.) and “all event” (75 b.p.) sets, which Gagnon et al. (2011a,b) interpreted as a “signaling” effect. That is, the FOMC was telling markets that it would keep overnight rates lower for longer. Likewise, the authors interpreted the fall in the 10-year

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16 The 10-year swap rate is a market-based estimate of the expected future interest rate over the next 10 years as it is the fixed interest rate exchanged for a benchmark variable rate plus or minus a spread.
term premium, in both the baseline (71 b.p.) and “all event” (47 b.p.) sets, as indicating an active portfolio balance channel. Thus, the study found support for both the signaling and portfolio balance channels of unconventional policy.\footnote{In a private communication, Matt Raskin explained to me that the Gagnon et al authors were reluctant to use changes in the swap rate to estimate the changes in expected future short rates because they feared that such changes would be contaminated by large and systematic changes in risk premia over the announcement windows.}

D’Amico and King (2013) investigate the microstructure effects of specific Fed purchases. That is, they use security-level data on Treasury prices and quantities to investigate the existence of local supply/scarcity effects of QE1. Local supply/scarcity effects imply that the yields of the Treasuries are more sensitive to the changes in amount outstanding in their own sector compared to other similar sectors. The effects from actual purchases of specific Treasury issues are decomposed into stock and flow effects and the authors use an instrumental variables technique to address the endogeneity of the asset purchases. The authors find a 30 basis point decline in Treasury yields over the duration of the program, the stock effect, and a 3.5 basis point decline due to the actual purchases on the days the operations occurred, the flow effect.

**Housing:** FOMC statements and speeches repeatedly emphasized special support for housing markets. Indeed, the FOMC stated that the initial LSAPs were intended to “reduce the cost and increase the availability of credit for the purchase of houses, which in turn should support housing markets and foster improved conditions in financial markets more generally.”\footnote{See the 11/25/2008 FOMC press release (Table A1). The purchases did not increase the exposure of U.S. taxpayers to GSE bonds, however, as the Congress had explicitly guaranteed all debts and liabilities of the GSEs earlier that fall, making the GSE debt and MBS close substitutes for long-term Treasury securities.}

Unsurprisingly, the Fed’s November 2008 and March 2009 asset purchase programs—commonly called “QE1”—prioritized housing and credit markets in the sense that Housing GSE debt and MBS accounted for more than 80 percent of QE1 assets purchased. In view of this, researchers have carefully studied the effects of unconventional policy on the housing credit market.

Because of the emphasis that the FOMC placed on the housing market, researchers have extensively examined the behavior of related bonds. For example, Gagnon et al.’s (2011b) studied a wide variety of bond yields, including bonds associated with the housing market and corporate bonds. But this study did not reveal whether specific purchases of MBS in QE1 influenced mortgage rates more than equivalent purchases of Treasury bonds in QE2. To investigate that question, Krishnamurthy and Vissing-Jorgensen (2011) compare the (scaled) yield reactions to QE1 and QE2, in which the Fed purchased only Treasuries. Krishnamurthy and Vissing-Jorgensen (2011) find that around QE1 announcement dates, MBS yields, as well as mortgage rates generally, declined significantly. They argue that specific purchases of agency MBSs by the Federal Reserve drove the decline in mortgage rates. In particular, for mortgage rates, the authors conjecture that purchases drove most of the fall through the “safety channel” while purchases reduced agency MBS yields through the “mortgage prepayment risk” channel.
In contrast, Krishnamurthy and Vissing-Jorgensen (2011) find that QE2 Treasury purchases reduced both mortgage and MBS yields, but the effects on MBS yields were much smaller. They interpret the smaller (scaled) effect by lack of direct reduction in mortgage market prepayment risk. In fact, the authors find that the fall in MBS yield changes around QE2 announcement dates can be fully accounted for by the signaling channel, rather than elements of the term premium.

Other authors also studied potential time variation in effects from QE1 to QE2. Meaning and Zhu (2011) use event study and local-stock analysis, a la D’amico and King (2013) to study the effects of QE1 and QE2. The authors interpret their evidence to indicate that both the event study announcement effects and the specific local effect declines after QE1. The authors suggest that the switch to purchasing Treasuries, rather than MBS and Agency debt, could contribute to the reduced effect. Martin and Milas (2012) also note that the event study effects of QE1 on long yields appear to be larger than those of QE2. They ascribe this seeming time variation to the facts that rates were already low or QE1 had eased financial stresses.

It seems very unlikely, however, that the limited event study evidence supports such a strong conclusion about time variation in the effect. It seems more likely that sampling variation and the failure to capture all events that raised purchase expectation were at least as important as the level of interest rate or the decline in financial stress.

Fuster and Willen (2010) use a complementary event-study approach to investigate how the Federal Reserve’s purchase of agency MBSs affected the US mortgage market. They bring evidence from a novel microeconomic data set that includes information on the entire menu of mortgage options available to borrowers, as well as data on quantities. Specifically, they have information on loan searches, applications, rejections, and acceptances. Their use of detailed microeconomic data sets their study apart. These detailed data show that announcement of the agency MBS purchases on November 25, 2008 reduced interest rates for borrowers but the degree of reduction depended on borrower characteristics. For instance, borrowers with poor credit (FICO scores) got smaller rate reductions than those with good credit. But the program produced mixed effects: the MBS purchase announcements increased searches, applications, and acceptances in the primary loan market. They also find that the announcement of agency MBS purchases increased both applications and mortgage originations. The increased activity in the primary loan market was confined to refinancing, it did not translate to increased original mortgages, however, as the number of mortgage applications or originations associated with house purchases was unaffected.

Corporate: Corporate bonds differ from Treasury debt, Agency MBS and Agency debt in that they are not backed by the full faith-and-credit of the U.S. government and therefore their yields reflect the risk that they will default. Unconventional monetary policy can reduce the default risk by stimulating the economy (or producing such expectations) and thereby reducing the probability of bankruptcy. LSAPs can also lead to lower investor risk aversion by generating expectations of improved financial and macroeconomic conditions. In addition to reducing “default risk,” unconventional policies can also reduce corporate yields by shoring up the balance sheets of
financial intermediaries. “Intermediary asset-pricing” theories posit that financial intermediaries’ balance sheets play a critical role in pricing of corporate bonds, because such intermediaries are the marginal investors in the market. This suggests that LSAPs can lower corporate yields by raising the capital of financial intermediaries, say by propping up asset prices, and increasing their capacity to bear risk. Finally, the usual signaling channel can also affect corporate yields through expectations of future Federal Reserve policy, as well as possibly through the safety channel for very high grade bonds. Researchers have studied these possible transmission channels of unconventional policy with several different methods.

In their event-study, Krishnamurthy and Vissing-Jorgensen (2011) infer the role of the default risk channel with data on corporate yields and credit default swap (CDS) rates. One can infer how unconventional policy changes the risk of default by contrasting the impact of LSAP policy announcements on high- and low-grade corporate bond yields. Because CDSs provide insurance on a bond default, one can infer the market’s estimate of the likelihood of default directly from the price of a CDS. Moreover, corporate yields adjusted for CDS rates can be used to filter out the default risk channel, and thereby assess which other channels could be at work. The authors find that corporate yields fall significantly around QE1 announcement dates and CDS rates on low grade bonds fall quite dramatically. This suggests that QE1 played an important role in decreasing default risk or the default risk premium in the economy. In one innovative exercise, the authors assess the announcement effects on corporate yields that have been adjusted for CDS rates to remove the default risk channel. While the results are statistically noisy, these adjusted rates tend to fall more on high grade bonds, which suggests a role for the safety channel. Moreover, analysis of these adjusted rates indicates that the signaling channel cannot fully account for effects on some high grade bonds. For QE2 dates, the authors find no evidence for the default risk channel and also infer that the signaling channel can account for almost all changes in the corporate bond yields. That is, QE2 did not affect term premia.

Krishnamurthy and Vissing-Jorgensen (2011) draw three conclusions from their work on MBS purchases and corporate yields: 1) Central banks should not focus solely on sovereign debt yields but also on corporate and mortgage rates; 2) Asset purchases of non-sovereign debt have the greatest impact on non-sovereign markets; And 3) asset purchases have their greatest effect through the signaling channel, by reducing expectations of future short rates.

The immediate goal of unconventional monetary policy was to lower yields and bond spreads, in order to reduce the cost of investment. This suggests that unconventional policy should have stimulated corporate bond issuance. Lo Duca, Marco, Giulio Nicoletti, and Ariadna Vidal Martinez (2016) investigate this question and find that U.S. unconventional policy did, in fact, substantially increase corporate bond issuance, especially in emerging markets, even after controlling for weakness in the international banking sector.

**Equities:** Early researchers on unconventional monetary policy were a bit puzzled because a given LSAP-induced change in long yields did not raise equity prices as much as an equivalent
change in long yields induced by an increase in the federal funds rate (Rosa (2012)). Indeed, Kiley (2014) shows that the correlation between long yield changes and equity returns is larger under conventional monetary policy. The fact that long-bond purchases lower long yields through different channels than does conventional monetary policy might explain this fact. Kiley (2014) shows that the ZLB complicates the effect of monetary policy on equity prices because it precludes a decline in short rates. That is, a given decline in long yields is associated with a smaller rise in equity prices during the ZLB period. But the impact of monetary policy on equities should depend on both short and long rates. Kiley (2014) uses instrumental variables regression because yield changes imperfectly measure the unobservable impulse of unconventional policy that actually drive asset price changes. The impact of long rate changes alone on equity prices is fairly similar between the two periods but the total impact of monetary policy appears to be lower because the short-rate is constrained by the zero lower bound. The author suggests circumspection in assessing the effect of long rates on equity prices and, by way of this channel, real activity.

Hattori, Schrimpf and Sushko (2016) showed that unconventional policy announcements reduced near-term option-implied tail risk—the risk-neutral implied probability of extreme events—in equity and interest rate markets, although it did not affect equity volatility, i.e., VIX. Using value-at-risk calculations, the authors interpret their finding as indicating that unconventional announcements relax balance sheet constraints for constrained investors. The authors suggest that their findings indicate that greater attention should be paid to the risk-taking channel of monetary policy.

The authors attempt to decompose the separate effects of purchase announcements and forward guidance with a regression of changes-in-risk on indicator variables for purchase news and forward guidance news, finding that the forward guidance indicator variables “explain” much larger effects on tail risk that do purchase indicators. The use of such indicator variables to stand in for very heterogeneous types of announcements—some of which contained little or even negative news about unconventional policy—is of questionable value.

**International:** Neely (2015) used event study methods, similar to those used by Gagnon et al.’s (2011a,b), to show that the Federal Reserve unconventional policy (QE1) announcements substantially reduced international sovereign bond yields and the value of the U.S. dollar on foreign exchange markets. Neely (2015) followed Gagnon et al (2011a,b) in defining two event sets: the first is a narrow event with only 8 events that specifically pertain to unconventional policy announcements while the second is broader, with 21 events that include the narrow event set, all FOMC events and minutes releases from November 2008 to 2010. Table 4, excerpted from Neely (2015), shows that foreign yields fell by 21 (43) basis points in the broad (narrow)

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19 Contemporaneously to the first draft of Neely (2015), Joyce et al. (2011) found that the Bank of England’s quantitative easing program had quantitatively similar bond yield effects as those found by Gagnon et al. (2011a,b) for the U.S. program.
event sets, respectively. Likewise, Table 5 shows that the total depreciation of the USD over the
broad (narrow) event sets is about 10 (6) percent. These jump depreciations of the USD are fairly
consistent with estimates of the impacts of previous equivalent, conventional monetary policy
shocks. The QE1 announcements appear to have moderately raised stocks and oil prices, from
which Neely infers that the policy announcements do not appear to have reduced yields by
reducing expectations of real growth. The author shows that the size of the estimated event-study
effects of the Fed’s unconventional announcements on international yields are consistent with the
quantified predictions of a portfolio balance model, calibrated to historical data, but he does not
directly evaluate the relative importance of signaling/portfolio balance effects. Neely concludes
that unconventional policy can reduce international long-term yields and the value of the dollar
even at the zero bound.

The strong effects that Neely found on international asset markets are consistent with the
results of Ait-Sahalia, Andritzky, Jobst, Nowak and Tamirisa (2012), who found positive
international spillovers from domestic financial market interventions and with Rogers, Scotti,
and Wright (2014), who compared unconventional policy shocks from the Federal Reserve Bank
of England, European Central Bank and Bank of Japan, finding that U.S. shocks exhibited the
greatest international spillovers.

**Emerging Market Effects:** Bowman, Londono and Sapriza (2015) use the identification-
through-heteroskedasticity methods of Rigobon (2003) and Wright (2012) to identify US
monetary policy shocks on sovereign bond yields, USD foreign exchange rates and stock prices.
They employ a daily VAR(1) with data from January 2006 to December 2013 from 17 emerging
market economies. U.S. monetary policy shocks generally lower 10-year EME yields but the
effect is often not statistically significant. At the aggregate level, a 25-basis point, expansionary
policy shock to US 10-year yields reduces EME sovereign yields by about 20 basis points. Using
the metric of any statistically significant effect over the first 100 days, the authors find a
statistically significant in 10 of the 17 countries. Curiously, the statistical significance of the
effect is sometimes delayed for weeks after the shock. Also, the confidence intervals for the IRFs
often fail to contain the point estimates. The VARs also estimate that a 25 basis point reduction
in the 10-year US bond yield reduces the value of the USD by 0.5 percent against the EME
currency basket, but this effect is not significant. The effect on stock prices is also insignificant.
An event study confirms the inference from the VARs.

The authors go on to investigate the cross-sectional determinants of changes in yields for the
EMEs using a panel regression with monthly data. The dependent variables are the monthly
change in the 10-year yield of the emerging market economies and the independent variables
include the change in the US 10-year yield and a high-yield US bond spread. The coefficients
depend on country characteristics. The authors find that riskier countries respond more strongly
to US variables and that there is greater heterogeneity in the response of countries to the US
spread variable than to the 10-year yield change.
**Term structure models:** To the extent that the previous event study papers would infer the relative importance of policy signaling on expected overnight interest rates and portfolio balance effects on term premia, they did so by estimating the expected overnight interest rate with the swap rate. TSMs are time series models of the evolution of the stochastic discount factor (SDF) that imply time paths for bond prices and therefore movements in the yield curve. They provide an alternative to swap rates to measure expected future overnight interest rates because one can assess the effect of any announcement on the predicted path. Several sets of authors have combined TSMs with event studies to assess the relative contributions of signaling and portfolio balance effects, where signaling effects would be taken as the effect of a policy announcement on the model-implied expected overnight interest rate and the portfolio balance effect would be taken as the residual effect of the announcement on long yields.

Gagnon et al. (2011) employ term structure calculations from the Kim-Wright (2005) model to infer that portfolio balance effects dominate, and that signaling effects are therefore negligible. In contrast, Bauer and Rudebusch (2013) and Christensen and Rudebusch (2012) claim that the signaling channel accounts for 30–65% of the total impact, rather than the 30% suggested by Gagnon et al.’s (2011a) analysis. A key difference between the two sets of estimates is that Bauer and Rudebusch (2013) and Christensen and Rudebusch (2012) correct for small-sample bias in estimating the TSM.

Bauer and Neely (2014) use several types of TSMs to analyze the channels through which the Fed’s unconventional policy announcements from 2008 to 2012 (QE1, QE2, and QE3) influenced international — U.S., Canadian, German, Australia and Japanese — sovereign bond yields. The authors decompose QE’s effect on zero-coupon foreign bond yields in local currencies with TSMs and then show that each country’s bonds characteristics help determine the importance of signaling vs. portfolio balance channels for that country. That is, countries whose yield curves were ordinarily sensitive to conventional U.S. monetary policy shocks exhibited large signaling effects on their yields. Likewise, countries whose bond yields historically tended to covary strongly with U.S. bond yields exhibited large portfolio balance effects.

Bauer and Rudebusch (2013), Christensen and Rudebusch (2012), Bauer and Neely (2014) and Hattori, Schrimpf and Sushko (2016) emphasize that changes in short-rate expectations should be viewed as conservative estimates of the importance of the signaling channel because successful unconventional policies will tend to raise expected future short rates, even as they reduce term premia. Such policies will also reduce interest rate risk and the term premium, even without any portfolio balance effects.

**Shadow rate studies:** Researchers have developed specialized TSMs to measure the stance of monetary policy when the traditional monetary policy instrument reaches the zero lower bound. These take the form of a shadow rate TSM, following the important work of Black (1995), which respects the zero lower bound constraint on the short-term nominal interest rate. In such models,
the short-term interest rate is modelled as the maximum of the shadow rate and the zero lower bound, where the shadow rate itself is a Gaussian (and linear) function of state variables.

In particular, Krippner (2013a, 2013b) and Wu and Xia (2016) proposed approximations that yield estimates of the short interest rate using data on forward rates. Krippner (2013b) shows that the shadow rate estimated for the US went negative around November 2008, the first LSAP I announcement date, and then decreased further on August 2010, another announcement date of further stimulus by the Federal Reserve. Moreover, it has increased since May 2013, the so-called taper tantrum date. Wu and Xia (2016) show that the shadow rate has been negative and variable in the post-ZLB, LSAP period. Using a factor-augmented VAR and counterfactual exercises, they provide evidence that LSAPs have played a role in lowering the shadow rate. Moreover, in an event-study approach, they further show that the shadow rate declined during announcements of major LSAP programs, while it increased during the taper tantrum.

**Dynamic announcement impact:** Many event studies have shown that central bank announcements of forward guidance and asset purchases had large and desired effects on asset prices and such studies also allow us to infer what channels produce these effects. They do not tell us, however, how long such effects last. The persistence of such effects is important because transient effects on yields or other assets will have much smaller effects on the real economy.

To investigate such persistence, Wright (2012) used a 1-lag structural vector autoregression (SVAR) to model the dynamic behavior of U.S. interest rates after unconventional policy shocks from QE1. Wright’s results indicate that unconventional policies have very transient effects on bond yields, with half-lives of 3 to 6 months after the initial announcement. Such brief effects would cast serious doubt on the efficacy of asset purchase programs because their effect on interest rates would be ephemeral.

Neely (2016) examines Wright’s SVAR procedure and argues that the SVAR is probably misspecified because it fails tests of structural stability and forecasts very poorly. In addition, the SVAR implies far too much in-sample return predictability to be consistent with rational asset pricing and reasonable risk aversion. Neely (2016) goes on to claim that restricted models that respect more plausible asset return predictability are more stable and imply that the unconventional monetary policy shocks were fairly persistent. Estimates of the dynamic paths of asset prices should respect the limited predictability in asset prices.

In contrast to the usual assumption that asset markets react quickly, within minutes or hours or a day or two, Mamaysky (2014) reasons limits to arbitrage could produce delayed responses to announcements in some types of markets. Therefore, Mamaysky estimates the impact of monetary policy announcements as the “most unusual” response—the response with the most extreme p-value—over a period of 21 business days. The paper reexamines unconventional monetary policy announcements from the Federal Reserve, the Bank of England and the European Central Bank (ECB). The author uses a bootstrap procedure to correct for the bias
inherent in looking for the most unusual reaction in a large group of correlated reactions. Importantly, this analysis illustrated that complex and often unexpected QE announcements policies had their full effects on equity markets over a period of some days.

**Quantity of debt regression studies:** A number of researchers have used lower frequency regression studies to complement or substitute for event study evidence. Such a strategy makes a lot of sense, in principle. Event studies must make assumptions and the use of other methods of analysis can check the robustness of these assumptions.

The second part of Gagnon, Raskin, Remache, and Sack (2011) uses monthly data from January 1985 to June 2008 to attempt to explain the Kim Wright 10 year term premium ($TP_{t}^{KW}$) and the 10-year Treasury yield. In the term premium regression, the regressors include net government bond supply variables, as in Backus and Wright (2007), as well as a vector of control variables ($X_t$) unemployment gap, core CPI inflation, long-run inflation disagreement, the 6-month volatility of the 10-year Treasury yield, the publicly held Treasury securities with at least one-year to maturity, Treasuries in the Fed’s SOMA account and US debt held by foreign official agencies. The regressors in the 10-year yield specification also included the fed funds target and the slope of the Eurodollar curve to proxy for the expected path of short rates.

$$TP_{t}^{KW} = a + b \cdot bond\ supply_t + c \cdot X_t + e_t$$ (4)

All these regressors are highly statistically significant. The authors conclude that the Federal Reserve's asset purchase announcements lowered long-term private borrowing rates which should stimulate economic activity. Using the regression results the authors estimate that QE1 decreased the term premium by 52 basis points and the 10-year Treasury yield by 82 basis points. Dynamic OLS of Stock and Watson (1993) provided similar to results to conventional regressions.

The second part of Krishnamurthy and Vissing-Jorgensen (2011) complements the event studies in the first part of that paper with a regression approach similar to that of Gagnon, Raskin, Remache, and Sack (2011). The authors regress long corporate-Treasury yield spreads on the maturity structure of government debt-to-GDP along with controls for volatility and the slope of the yield curve with annual data, 1949 to 2008. The regressions use total-debt-to-GDP as an instrument for the maturity weighed debt-to-GDP, reasoning that total debt is not responsive to the slope of the yield curve in the same way as maturity weighed debt-to-GDP. The regressions find that an increase in the maturity structure of government debt reduces the corporate-Treasury spreads in a statistically significant fashion.

Thornton (2014) investigates the robustness of the reduced-form regressions of Gagnon et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011) to different measures of debt and the presence of a time trend in the regressions. Specifically, Thornton argues that the regression results are highly dependent on the presence of time trends in the data that produce a spurious correlation between the supply of Treasuries and yields. Thornton’s regressions indicate that the
public’s holdings of debt has no effect on yields — or even a negative effect — if a time trend is included in the regression.\textsuperscript{20} The time trend is generally highly statistically significant.

**Analysis of debt regression studies:** These regression studies of the effect of debt supplies on yields have a number of potential problems, which may affect one’s confidence in their results. First, as the studies acknowledge, the maturity and size of debt is endogenous. For example, governments might issue more debt when yields are low. Another potentially serious problem is that the variables—yields, spreads, debt ratios— are usually very persistent. Persistent variables create non-standard distributions of the coefficient estimates even in the case of proper specification and potential problems with spurious regression estimates. Related to the problem of persistent variables is the issue of whether and how to include trends. Thornton’s (2014) criticism of the regression analysis of Gagnon et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011) implicitly concedes that a regression analysis of yields on bond supply and control variables is perfectly valid but that one obtains a negative result—that bond supplies have no effect on yields—if one treats trends properly. In addition to the problems of endogeneity, persistent variables and/or treatment of time trends, the regression of yields (or spreads) on bond supply variables is subject to a more fundamental criticism: Financial markets are forward looking and government debt is probably fairly predictable. For example, the fact that US government debt would increase substantially from the tax cuts and defense buildup of the 1980s was obvious many quarters, if not years, before the debt was on the books. This is a fundamental problem with low-frequency studies of financial variables, including those surveyed in this section.

**Regression studies of the MBS purchase program:** A pair of papers, by Hancock and Passmore (2011) and Stroebel and Taylor (2012), employed regressions to examine the success of the Fed’s MBS purchase program, coming to diametrically opposed conclusions as to its usefulness.

In the first half of their paper, Hancock and Passmore (2011) usefully describe the mortgage/MBS market in the years leading up to the financial crisis, including the decline in premia for prepayment risk. The authors define two subsamples prior to the crisis, the “normal” sample (July 2000 - March 2004) and the era of “subprime dominance” (April 2004 - July 2007).

Pursuing a mostly narrative and indirect approach to assess the success of the Fed’s MBS purchase program, the authors note that MBS yields fell substantially with the announcement of the Federal Reserve’s MBS purchase program and they credit that program with removing risk premia from MBS yields. Interestingly, the authors make the case that the full effect of the MBS purchase program in the secondary market was not felt until the Fed started to actually purchase securities.

\textsuperscript{20} Furthermore, Thornton asserts that the portfolio-balance effect is theoretically implausible. This seems to be an overly bold claim in view of work by Vayanos and Vila (2009), Farmer (2012) and others.
Moving on to an examination of mortgage rates themselves, Hancock and Passmore (2011) document that the mortgage-Treasury spread declined substantially during the Fed’s MBS purchase program. Using out-of-sample predicted values from a regression of mortgage rates on MBS yields and house prices, the authors argue that the Fed’s interventions were helping to bring down mortgage rates by about 100 basis points and long rates more generally.

Stroebel and Taylor (2012) also set out to examine the effect of the MBS purchase program on mortgage interest rate spreads, using weekly data between 2007 and June 2010 (179 observations). The authors focused on the option-adjusted spread (OAS), which is the additional yield over the LIBOR yield curve that an MBS security would deliver, after adjusting for the prepayment risk to which the MBS is subject. That is, the OAS spread is the compensation for bearing normal duration risk and the default risk associated with the MBS. The authors regressed a wide variety of OAS measures on bond-spread variables to control for default risk and on MBS purchase variables, including the cumulative total Fed MBS purchases, dummies starting at the Treasury’s and Federal Reserve’s first purchase dates, the announcement of the program expansion in March 2009. Generally, many — but not all — of the coefficients on QE programs are positive or insignificant coefficients, which the authors interpret as indicating that the program had no effect on the swap-OAS. Cumulative QE purchases, which is a very persistent regressor, often has a statistically significant perverse sign, probably as a result of a spurious regression, which the authors curiously interpret as somehow canceling out evidence that other QE variables that have significant negative signs. Instead, the authors attribute the declines in the mortgage rates to declines in prepayment risk and default risk.

How can one reconcile Hancock and Passmore’s (2011) positive assessment of the MBS program with Stroebel and Taylor’s (2011) equally negative assessment?

First, one should note that while the two studies both drew conclusions about the MBS purchase program, they focused on different variables. While Hancock and Passmore (2011) looked at a decomposition of mortgage rates into its mortgage-MBS spread and MBS-swap spread, Stroebel and Taylor (2012) focused on a much more narrowly defined variable, the OAS spread. MBS yields are essentially the sum of expected future short-rates and premia for prepayment risk, default risk and duration risk. By using the OAS spread in regressions with controls for default risk, it seems that duration risk is the only significant component left for QE to explain.

Second, event study evidence appears to be consistent with the hypothesis that the MBS purchase program lowered MBS yields and mortgage rates. A QE1 event study shows that that MBS yields and the swap rate declined by 44 and 29 basis points on November 25, 2008 and by 31 and 39 basis points on March 18, 2009, suggesting that the program did, in fact, substantially reduce these rates. See Table 1 in Gagnon et al’s (2011a, b). That is, the unadjusted MBS-swap spread declined by 15 and -8 basis points on those two dates. Given the null that the QE program actually did reduce MBS yields by some modest amounts through both the signaling and
portfolio balance channels, how likely is it that a regression with three years of weekly data would uncover the true relation in OAS spreads?

Third, from an econometric point of view, both the OAS spreads and the bond spread variables appear to be persistent and follow similar patterns over the three-year sample, meaning that, as the authors themselves note, “Little remains to be explained by MBS purchases” (Stroebel and Taylor (2012), page 20). It remains an open question whether one could expect to find plausible QE effects on duration premia from such a regression exercise.

Regression analysis of corporate credit risk: Gilchrist and Zakrajsek (2013) study the effects of LSAPs on market-based indicators of corporate credit risk, that is, credit derivative indices, with a daily regression that employs an identification-through-heteroscedasticity approach that exploits the higher variance of policy shocks on known announcement dates. Then one can infer the causal response of asset prices to changes in policy. This is a simultaneous system of equations framework. The authors thus posit first that LSAP announcement dates have an effect on safe rates such a long term Treasury rate, which is their measure of a policy rate. The second equation in the framework then models the effect of the safe rate on corporate credit risk. They then estimate the “causal” effect of changes in the policy rate on corporate credit risk, using the identification-through-heteroscedasticity approach that relies on an instrumental variable approach.

Gilchrist and Zakrajsek (2013) mainly use publicly available credit derivative indices to measure credit risk at the economy-wide level, for both investment grade and speculative grade bonds. They also construct indices of financial sector credit risk using CDS contracts on commercial banks and securities broker-dealers. They find that unconventional policy announcements, which include LSAP-I, LSAP-II, and MEP dates identified by Krishnamurthy and Vissing-Jorgensen (2011), broadly reduced default risk for both investment grade and speculative grade bonds. At the same time however, they find no evidence that unconventional policy announcements decreased default risk of the financial sector. The main contribution of this work is to use an alternate identification approach, compared to an event-study approach, to assess the effects of LSAPs on corporate yields.

Segmented markets analysis: Greenwood and Vayanos (2014) focus directly on the portfolio balance channel by organizing their empirical analysis based on Vayanos and Vila’s (2009) segmented-markets model. Specifically, they use a TSM to motivate and inform the predictions of a regression model that predicts yields and returns with two measures of government debt supply: maturity-weighted debt to GDP, and long-term debt to GDP. The authors use a postwar sample, 1952 to 2007, and an interwar sample, 1916–1940. To avoid endogeneity bias, the authors instrument maturity-weighted debt to GDP with marketable Treasury debt to GDP. The authors find a positive relation between maturity-weighted debt-to-GDP and long yields. Their regression estimates imply that QE1 and QE2 together reduced yields by 40 basis points, which is smaller than the event-study estimates of Gagnon et al. (2011), D’Amico, English, et al.
(2012), and Li and Wei (2012), which are in the 90 to 100 basis point range for those two episodes. Supply changes have much larger effects on short-term expected returns than they do on yields. The results are robust to instrumenting the independent variable with debt to GDP, which is mostly predetermined by past debt.

Hamilton and Wu (2012) also adapt the model of Vayanos and Vila (2009) to a discrete time framework in order to study how the maturity of government debt affects the term structure of interest rates using yield and debt data from 1990 to 2007. But, in contrast to the methods of Greenwood and Vayanos (2014), Hamilton and Wu (2012) use a calibrated, discrete Vayanos and Vila (2009) framework, along with assumptions on the probability that agents assign some probability of exit from ZLB and the behavior of interest rates after this exit, to study the consequences of decreasing the maturity of outstanding government debt on long-term yields. They estimate that the impact of a $400 billion purchase of long-term maturities would reduce the 10-year rate by 13 basis points. This estimate is fairly consistent with event study point estimates of the effects of QE1 announcements that put the effects of a $1.725 trillion purchase at between 40 and 100 basis points on the 10-year Treasury. Li and Wei (2012) use a TSM with observable and supply factors to find term premia effects of QE1 and the maturity extension program.

5. U.S. Unconventional Policy Effects on the Macro Economy

The evaluation of unconventional monetary policy must have two parts. The first part is to assess the effects of the policy on asset markets, interest rates, stock prices, exchange rates, etc. The second, and perhaps more difficult, part is to connect the changes in asset prices to broader macroeconomic outcomes. Studying the effect of unconventional policy on the macro economy is both more important and more difficult than studying its effects on asset prices and yields. It is more important because the ultimate goals of central banks pertain to output, inflation and, eventually, consumer welfare. It is also more difficult because problems of endogeneity, simultaneity, omitted variables, specification error and measurement errors are much more serious than for financial markets, which are amenable to the use of “event studies” to gauge the effects of policy announcements. To study the effect of unconventional monetary policy on macro variables, one must use low frequency data and control for non-monetary factors.

Several groups of authors have tried to investigate the impact of unconventional monetary policy on macro variables with conventional empirical macro modeling tools: dynamic stochastic general equilibrium (DSGE) models and vector autoregressions (VARs).

**Calibrated DSGE models:** One method to assess the macroeconomic implications of LSAPs is to use simulations from calibrated DSGE models that feature a role for unconventional policy. Specifically, the model can be simulated without unconventional monetary policy interventions in a ZLB situation to assess the negative effects on output and inflation. Then, the model can be
rerun with a policy intervention sized to resemble a particular LSAP episode, such as QE2, or with a change in the composition of the Federal Reserve balance sheet as in QE3. The difference in outcomes as a result of the policy intervention then measures the model-implied macroeconomic effects of LSAPs. Researchers have used such a strategy to assess the macroeconomic implications of both the portfolio balance and signaling channels.

Chen, Curdia, and Ferrero (2012) calibrate their DSGE model that features preferred habitat preferences, and thus a role for the portfolio balance channel, to assess the effects of LSAPs. They find that a $600 billion purchase of long-term government bonds (roughly matched to the announcement of the QE2 program), together with a credible commitment to hold short-term interest rates at zero for four quarters, increases GDP growth by 0.13% and inflation by 3 bp (both annualized). The bulk of the effects however, is due to the credible commitment by the central bank to hold short-term interest rates at zero in future. This suggests that the portfolio balance channel has weak effects on the macroeconomy.

The fact that Chen, Curdia, and Ferrero (2012) find an important role in their simulations for credible commitment by the central bank to hold short-term interest rates at zero in the future suggests that the signaling channel can be powerful in DSGE models. Bhattarai, Eggertsson, and Gafarov (2015) calibrate their DSGE model that features a central bank with balance sheet concerns that conducts policy under discretion, and thus a role for the signaling channel, to estimate the effects of LSAPs. In particular, they assess the effects of changing the size of the Fed’s balance sheet and its duration mismatch and can therefore model both QE2 and MEP. They calibrate the signaling effects on long-term yields and expected inflation from estimates by Krishnamurthy and Vissing-Jorgensen (2011). Moreover, they target the drop in output, inflation, and expected duration of the ZLB to be roughly consistent with the Great Recession. The results from the calibrated model implies that QE2, which doubles the size of the Federal Reserve’s balance sheet in their calibration without changing much the duration mismatch in Treasury holdings, increased output by about 45 bp. Then they estimate that QE3 or MEP/Operation Twist, which increases the average duration of Treasury bond holdings by around 5 quarters without changing the size of the Federal Reserve’s balance sheet, increased output by about 12 bp. The results suggest that QE2 stimulated the economy more effectively than QE3.

VARS: Vector autoregression (VAR) is another popular method to assess the macroeconomic implications of LSAPs. VARs allow researchers to estimate the macroeconomic effects of unconventional monetary policy with macroeconomic and financial data. VARs in this literature typically use monthly data because that is the highest frequency at which most macroeconomic data, such as on output and prices, is available. VARs require fewer explicit assumptions about behavior of consumer and firms than do DSGEs, but they need a convincing strategy to identify policy shocks. Although the Federal Funds rate, perhaps augmented with “path” shocks, is widely accepted as the appropriate instrument of conventional monetary policy, the choice of a monetary instrument is more controversial during the ZLB period. Conditional on the
researcher’s choice of the appropriate unconventional monetary policy instrument, the rest of the VAR analysis can then be undertaken in a fairly standard fashion. That is, with some plausible identification assumptions, such as impact restrictions on the sign or size of response of certain variables to policy, the anticipated component of policy can be separated from the unanticipated component. The response of macroeconomic variables to the unanticipated component of policy, or the policy shock, can then be estimated and traced out.

Gambacorta, Hofmann, and Peersman, (2014), in an early study, estimate a panel VAR with feasible generalized least squares (FGLS) on monthly output, price, VIX and central bank assets data from 8 countries — Canada, the euro area, Japan, Norway, Switzerland, Sweden, the United Kingdom and the United States—over the sample January 2008 to June 2011. Using sign restrictions to identify the VAR, the authors conclude that an exogenous increase in central bank assets, which they consider to be the monetary policy instrument at the zero lower bound, temporarily increases output and prices. Cautioning that their results are specific to the crisis period, they also report that unconventional monetary policy shocks have larger output and smaller price effects than conventional monetary policy shocks.

Bhattarai, Chatterjee, and Park (2015) also estimate the impact of U.S. QE using a structural Bayesian VAR with contemporaneous restrictions, under the assumption that the size of Federal Reserve assets (the monetary bases) functions as the instrument of monetary policy. The authors estimate the model on monthly U.S. macroeconomic and financial data, but focus on spillover effects on emerging market economies. Unanticipated fluctuations in Federal Reserve assets produce substantial macroeconomic and financial effects on the U.S. economy and substantial financial effects on emerging market economies. Additionally, the paper provides evidence of heterogeneous reactions among sub-groups of emerging market economies, with stronger effects on the so-called “Fragile Five” countries. These results clearly illustrate spillover effects of U.S. QE policy on emerging market economies.

Some other papers have used an interest rate spread as an instrument of QE policy in a VAR framework. Starting with a given estimate of the effects of QE on interest rate spreads, these papers identify the effects of a spread shock with standard restrictions and then indirectly assessed the macroeconomic effects of QE. This indirect but plausible method utilizes the substantial evidence of the effects of QE on interest rates/spreads. Researchers have used two important spread measures, mortgage spreads and long-term Treasury spreads, that have been known to affect the business cycle in this framework.

For instance, Walentin (2014) uses a structural VAR (SVAR) to argue that shocks to mortgage spreads — the mortgage rate less the Treasury rate of the same maturity — which he interprets as credit supply (policy) disturbances, have large macroeconomic effects in the US. Unanticipated increases in this spread reduce house prices, residential investment, consumption, and GDP. Walentin then indirectly estimates the effects of QE1 in a counterfactual exercise that imposes the ZLB on the Fed Funds rates and uses previous empirical estimates of the effects of
QE1 on mortgage spreads. The implied effects are economically large: at peak, consumption and GDP increase by 1.18 and 1.02 percentage points respectively, while residential investment and house prices increase by 6.74 and 3.00 percentage points respectively.

Similarly, Baumeister and Benati (2013) employ a time-varying parameter VAR framework to identify a pure term spread shock that leaves the federal funds rate unchanged but affects the 10-year Treasury yield. The authors estimate that reductions in this interest rate spread produce substantial macroeconomic effects during the ZLB period. Then, using the effects of asset purchases on the interest rate spread, the authors infer the effects of LSAPs on the macroeconomy, finding that such policies successfully averted deflation and output collapse.

As we discussed previously, the choice of policy instrument to use in a VAR is an important decision for researchers. Most studies use some measure of spread such as mortgage or term spread or the assets held outright in the Fed’s balance sheet during LSAP operations. Others have used measures of interest rates, such as shadow rates or long-term yields. For instance, Wu and Xia (2016) use their measure of shadow rate as a policy instrument during the ZLB period in a factor-augmented VAR and show that macroeconomic effects of an unanticipated change in the policy instrument are similar to the pre-ZLB period, where the federal funds rate is the policy instrument. Some other papers directly posit the effects of LSAPs on long-term yields or use a long-term yield as an instrument of the Federal Reserve during the ZLB period to assess the macroeconomic effects of falling yields in a VAR framework. Instead of a shadow rate, Gilchrist, Lopez-Salido, and Zakrajsek (2015) directly use the 2-year Treasury yield as an instrument of monetary policy. Around LSAP announcement dates, they show that there were significant changes in both that yield and longer term yields.

Finally, Weale and Wieladek (2016) employ a hybrid method that merges LSAP announcement effects approach with a monthly Bayesian VAR to assess the macroeconomic effects of these policies. The paper assumes that the QE policy instrument is the cumulated level of LSAP purchases, scaled by GDP. They employ a variety of identification schemes that do not restrict the effects of policy on output and inflation to assess the impact of asset purchases in the US and UK. These authors find that an asset purchase of 1% of GDP raises US (UK) GDP by 0.58% (0.25%) and CPI by 0.62% (0.32%), all of which are statistically significant.

6. Discussion and Conclusion

Since the inception of unconventional monetary policies by central banks around the world in 2008, a large literature has sprung up empirically investigating the impact of such policies on financial markets and the real economy. The theoretical literature that departs from a frictionless textbook financial sector provides a role for unconventional policies. In particular, new DSGE models can rationalize both the portfolio balance and the signaling channels of unconventional monetary policy. Models that allow households to prefer assets of a certain maturity provide a
role for LSAPs to be effective through the portfolio balance channel. Absence of costlessly credible commitment by the central bank suggests a role for unconventional monetary policy through the signaling channel. LSAPs that change either the size or composition of the central bank balance sheet can be effective through this channel. Likewise, models that introduce private sector limits to arbitrage have a role for unconventional policy in the form of direct lending to non-financial firms.

Researchers have employed several methods to assess the effects of unconventional policies on financial markets: 1) event studies; 2) regressions, including vector auto regressions, with lower frequency data; and 3) model simulation. Of these, event studies have been most commonly used to determine the impact of unconventional policy announcements on asset prices as well as to determine the channels by which such policies affect asset prices. Event studies have several advantages over research using lower frequency data. Specifically, the forward-looking nature of financial markets simultaneously makes event studies the appropriate tool for determining the long-run impact of policies while rendering regression studies with lower frequency data much less trustworthy.

A second strategy for examining the effect of unconventional monetary policy is to model long yields as a function of macroeconomic variables and the supply of long-term debt over a long period, perhaps decades. Unfortunately, this strategy runs into problems with endogeneity, simultaneity, treatment of persistent variables and structural instability. In addition, such a regression strategy would find it difficult to account for the fact that changes in expected bond supplies and the future path of short rates are the drivers of changes in yields—not changes in actual bond supplies and the current short rate.

Event studies have shown that unconventional policy announcements have had strong effects on domestic and international asset prices (Gagnon et al (2011a,b), Neely (2015)). The novelty of QE1 set it apart from later QE programs in that researchers could plausibly define a relatively small set of events that changed expectations about QE1. This allowed them to estimate the total effect of QE1 from those events (Gagnon et al (2011a,b), Neely (2015)). For example, a surprise announcement of a one trillion USD purchase of long-term bonds will reduce 10-year U.S. Treasury yields by about 30 to 50 basis points and foreign yields by 10 to 25 basis points. Low grade corporates fell similarly to U.S. Treasuries. The yields on MBS declined even more than Treasuries, falling 66 basis points. Mortgage rates fell further still (Krishnamurthy and Vissing-Jorgensen (2011)), Hancock and Passmore (2011)). Such a $1 trillion purchase will also reduce the value of the USD by 3.5 to 6 percent and raise stock prices by perhaps 1-1.5 percent (Neely (2015), Kiley (2014)). Consistent with a perception of a stimulatory effect on the economy, unconventional policy announcements reduced near-term option-implied tail risk—the risk-neutral implied probability of extreme events—in equity and interest rate markets (Hattori, Schrimpf and Sushko (2016)). Although the great majority of the effect of unconventional policy probably occurs with announcements that change market expectations, transactions themselves
do have local, microstructural effects that change yields on the specific issues purchased by a few basis points (D’Amico and King (2013)).

Event studies have proven the most useful method for evaluating asset price effects but the method has its limitations. Specifically, the small number of observations on unconventional policy announcements makes it difficult to estimate the impact with any precision. This imprecision, coupled with the difficulty of finding appropriate “surprise” components to the announcements also makes it very difficult to estimate time variation in the impact of the programs. Further, event studies assume that the full effect of the announcement occurs within the asset price window. This assumption is difficult to test because it is inherently difficult to determine the persistence of LSAP shocks with any precision. Rational asset pricing, however, implies that they are most likely very persistent (Neely (2016)).

Both the signaling and portfolio balance channels appear to be important conduits of unconventional policy. The international signaling and portfolio effects of unconventional policy are similar to those from conventional effects (Bauer and Neely (2014)). The international effects are not confined to developed countries but also spill over to reduce yields and boost stock prices in emerging markets (Bowman, Londono and Sapriza (2015)).

The type of asset purchased seems to affect the reaction to unconventional policy announcements. Depending on the asset purchased, such policies have reduced not just the riskless 10-year yields but also risk premia, such as default risk and prepayment risk. A clearly articulated goal of LSAPs was to support housing markets. Researchers have found evidence that purchases of MBSs decreased both MBS yields and mortgage rates. They have also found evidence, albeit smaller, in support of decreased in MBS yields and mortgage rates following purchases of Treasuries.

Some researchers have extended standard TSMs to account for the binding ZLB on the short-term interest rate. These models imply “shadow” short term rates that measure of stance of monetary policy during the ZLB period. The estimated shadow rates appear intuitively sensible as they tend to decrease around LSAP announcements and increase around the so called Taper tantrum (Krippner (2013a, 2013b) and Wu and Xia (2016)).

VAR studies of the impact of unconventional monetary policy on the macro economy suggest that unconventional monetary policy have substantial output and price effects both in developed countries and emerging markets (Gambacorta, Hofmann, and Peersman, (2014), Bhattarai, Chatterjee, and Park (2015), Walentin (2014), and Baumeister and Benati (2013)). Bhattarai, Chatterjee, and Park (2015) calculate that a 40 billion dollar asset purchase reduces increases industrial production and consumer prices by 0.4% and 0.1%, respectively, at a horizon of 10 months. Similarly, Weale and Wiedelak’s (2016) VAR analysis implies that an asset purchase of 1% of GDP raises GDP and CPI by 0.58% and 0.62%, respectively. Conditional forecasting analysis in the latter paper implies that QE1 raised GDP and CPI by about 2
percentage points at its peak, while QE2 raised GDP and the CPI by about 6 percentage points. Moreover, calibrated DSGE models also support the hypothesis that LSAP policies lessened the negative impact on output and inflation of a binding ZLB. This research shows that both the portfolio and signaling channel can in principle be effective in DSGE models (Chen, Curdia, and Ferrero (2012) and Bhattarai, Eggertsson, and Gafarov (2015)).
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Table 1: Types of bonds subject to types of risk

<table>
<thead>
<tr>
<th></th>
<th>Treasury</th>
<th>Corporate</th>
<th>Agency MBS</th>
<th>Agency debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration risk</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Default risk</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquidity premium</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepayment risk</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Local scarcity</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Safety premium</td>
<td>X</td>
<td>X (high-grade only)</td>
<td></td>
<td>X</td>
</tr>
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</table>
Table 2: Federal Reserve unconventional monetary policy announcements

<table>
<thead>
<tr>
<th>Date</th>
<th>Program</th>
<th>Event</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/25/2008</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>LSAP announced: Fed will purchase $100 billion in GSE debt and $500 billion in MBS</td>
</tr>
<tr>
<td>12/1/2008</td>
<td>QE1</td>
<td>Bernanke speech</td>
<td>First suggestion of extending QE to Treasuries</td>
</tr>
<tr>
<td>12/16/2008</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>First suggestion of extending QE to Treasuries by FOMC. Fed cuts Fed Funds rate from 1 percent to 0.00-0.25 percent; expects low rates &quot;for some time&quot;</td>
</tr>
<tr>
<td>1/28/2009</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>Fed stands ready to expand QE and buy Treasuries</td>
</tr>
<tr>
<td>3/18/2009</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>LSAP expanded: Fed will purchase $300 billion in long-term Treasuries and an additional $750 and $100 billion in MBS and GSE debt, respectively. Fed expects low rates for &quot;an extended period.&quot;</td>
</tr>
<tr>
<td>8/12/2009</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>LSAP slowed: All purchases will finish by the end of October, not mid-September</td>
</tr>
<tr>
<td>9/23/2009</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>LSAP slowed: Agency debt and MBS purchases will finish at the end of 2010Q1</td>
</tr>
<tr>
<td>11/4/2009</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>LSAP downsized: Agency debt purchases will finish at $175 billion</td>
</tr>
<tr>
<td>8/10/2010</td>
<td>QE1</td>
<td>FOMC statement</td>
<td>Balance Sheet Maintained: Fed will reinvest principal payments from LSAP purchases in Treasuries</td>
</tr>
<tr>
<td>8/27/2010</td>
<td>QE2</td>
<td>Bernanke speech</td>
<td>Bernanke suggests role for additional QE, &quot;should further action prove necessary&quot;</td>
</tr>
<tr>
<td>9/21/2010</td>
<td>QE2</td>
<td>FOMC statement</td>
<td>FOMC emphasize low inflation, which is &quot;is likely to remain subdued for some time before rising to levels the Committee considers consistent with its mandate&quot;</td>
</tr>
<tr>
<td>10/12/2010</td>
<td>QE2</td>
<td>FOMC minutes released</td>
<td>FOMC members &quot;sense&quot; is that &quot;additional accommodation may be appropriate before long&quot;</td>
</tr>
<tr>
<td>10/15/2010</td>
<td>QE2</td>
<td>Bernanke speech</td>
<td>Bernanke reiterates that Fed stands ready to further ease policy</td>
</tr>
<tr>
<td>6/22/2011</td>
<td>QE2</td>
<td>FOMC statement</td>
<td>QE2 finishes: Treasury purchases will wrap up at the end of month, as scheduled; principal payments will continue to be reinvested</td>
</tr>
</tbody>
</table>
Table 2: Federal Reserve unconventional monetary policy announcements (continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Program</th>
<th>Event</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/21/2011</td>
<td>MEP</td>
<td>FOMC statement</td>
<td>Maturity Extension Program (&quot;Operation Twist&quot;) Announced: Fed will purchase $400 billion of Treasuries with remaining maturities of 6 to 30 years and sell an equal amount with remaining maturities of 3 years or less; MBS and agency debt principal payments will no longer be reinvested in Treasuries, but instead in MBS</td>
</tr>
<tr>
<td>6/20/2012</td>
<td>MEP</td>
<td>FOMC statement</td>
<td>Maturity Extension Program Extended: Fed will continue to purchase long-term securities and sell short-term securities through the end of 2012. Purchases/sales will continue at the current pace, about $45 billion/month.</td>
</tr>
<tr>
<td>8/22/2012</td>
<td>QE3</td>
<td>FOMC minutes released</td>
<td>FOMC members &quot;judged that additional monetary accommodation would likely be warranted fairly soon…&quot;</td>
</tr>
<tr>
<td>9/13/2012</td>
<td>QE3</td>
<td>FOMC statement</td>
<td>QE3 Announced: Fed will purchase $40 billion of MBS per month as long as &quot;the outlook for the labor market does not improve substantially…in the context of price stability.&quot;</td>
</tr>
<tr>
<td>12/12/2012</td>
<td>MEP</td>
<td>FOMC Statement</td>
<td>Maturity Extension Program concludes. FOMC to begin purchasing longer-term treasuries at an initial pace of $45 billion per</td>
</tr>
<tr>
<td>12/18/2013</td>
<td>QE3</td>
<td>FOMC Statement</td>
<td>&quot;Beginning in January, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $35 billion per month rather than $40 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $40 billion per month rather than $45 billion per month.&quot;</td>
</tr>
<tr>
<td>1/29/2014</td>
<td>QE3</td>
<td>FOMC Statement</td>
<td>Fed will further reduce monthly asset purchases to $30 billion in MBS and $35 Billion in Treasuries</td>
</tr>
<tr>
<td>3/19/2014</td>
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<td>FOMC Statement</td>
<td>Fed will further reduce monthly asset purchases to $25 billion in MBS and $30 Billion in Treasuries</td>
</tr>
<tr>
<td>4/30/2014</td>
<td>QE3</td>
<td>FOMC Statement</td>
<td>Fed will further reduce monthly asset purchases to $20 billion in MBS and $25 Billion in Treasuries</td>
</tr>
<tr>
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<td>FOMC Statement</td>
<td>Fed will further reduce monthly asset purchases to $15 billion in MBS and $20 Billion in Treasuries</td>
</tr>
<tr>
<td>7/30/2014</td>
<td>QE3</td>
<td>FOMC Statement</td>
<td>Fed will further reduce monthly asset purchases to $10 billion in MBS and $15 Billion in Treasuries</td>
</tr>
<tr>
<td>9/17/2014</td>
<td>QE3</td>
<td>FOMC Statement</td>
<td>Fed will further reduce monthly asset purchases to $5 billion in MBS and $10 Billion in Treasuries</td>
</tr>
<tr>
<td>10/29/2014</td>
<td>QE3</td>
<td>FOMC Statement</td>
<td>&quot;the Committee decided to conclude its asset purchase program this month.&quot; The Committee continues to reinvest principal payments from agency MBS in MBS and roll-over maturing Treasuries</td>
</tr>
<tr>
<td>12/16/2015</td>
<td>FOMC</td>
<td>Statement</td>
<td>Committee votes to increase the target range for the policy rate to 1/4 to 1/2 percent, IOR changed to 0.5 percent</td>
</tr>
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Table 3: The impact of QE 1 events on yields, as excerpted from Table 1 of Gagnon et al (2011b)

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Two-Year U.S. Treasury</th>
<th>Ten-Year U.S. Treasury</th>
<th>Ten-Year Agency</th>
<th>Agency MBS&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Ten-Year Term Premium</th>
<th>Ten-Year Swap</th>
<th>Baa Index</th>
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<td>7</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>5</td>
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</table>

Baseline event set: -34, -91, -156, -113, -71, -101, -67
Baseline set + all FOMC: -1, -55, -134, -114, -47, -75, -72
Cumulative change 11/24/08 to 3/31/2010: -19, 50, -75, -95, 30, 28, -489
Std dev of daily changes: 5, 8, 9, 10, 6, 9, 7

Notes: The title to this table in the Gagnon et al paper is “Table 1: Interest Rate Changes around Baseline and Extended Event Set Announcements, Basis points”
Sources: Bloomberg L.P.; Barclay’s Capital; Board of Governors of the Federal Reserve System.

<sup>a</sup> Included in the baseline event set.
<sup>b</sup> Two-day change for agency mortgage-backed securities on March 18, 2009, because of a Bloomberg L.P. data error.
Table 4: Effect of the LSAP on U.S. and foreign long-term bond yields from Neely (2015)

<table>
<thead>
<tr>
<th>Buy Events</th>
<th>10YR</th>
<th>Canada 10YR</th>
<th>Germany 9-10YR</th>
<th>Japan 10YR</th>
<th>U.K. 10YR</th>
<th>Foreign Average</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-10</td>
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<td>-7</td>
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</tr>
<tr>
<td>12/16/2008</td>
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<td>3</td>
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<td>(0.02)</td>
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<table>
<thead>
<tr>
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<th>10YR</th>
<th>Canada 10YR</th>
<th>Germany 9-10YR</th>
<th>Japan 10YR</th>
<th>U.K. 10YR</th>
<th>Foreign Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/12/2009</td>
<td>-17</td>
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<td>-2</td>
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<tr>
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<tr>
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<th>Buy+Sell Sum</th>
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<th>Japan 10YR</th>
<th>U.K. 10YR</th>
<th>Foreign Average</th>
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<th>Germany 9-10YR</th>
<th>Japan 10YR</th>
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<th>Germany 9-10YR</th>
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<th>Foreign Average</th>
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Notes: The table shows one-day nominal U.S. and foreign long-term yield changes, in bp, around 8 LSAP news events and 13 FOMC control events, as well as sums over those event windows. The “p-values” in parentheses below the yield changes show the proportions of n-day yield changes from July 2007 through January 2010 that were larger in absolute value than the actual change in the n-day period around the event. The 13 control events consist of all FOMC meeting statements and minutes releases from November 2008 through January 2009 that are not “buy” or “sell” events.
Table 5: Effect of the LSAP on the foreign exchange value of the USD from Neely (2015)

<table>
<thead>
<tr>
<th>Buy Dates</th>
<th>AUD/USD</th>
<th>CAD/USD</th>
<th>EUR/USD</th>
<th>JPY/USD</th>
<th>GBP/USD</th>
<th>Average Δ in FX rate</th>
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<tbody>
<tr>
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<th>AUD/USD</th>
<th>CAD/USD</th>
<th>EUR/USD</th>
<th>JPY/USD</th>
<th>GBP/USD</th>
<th>Average Δ in FX rate</th>
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<td></td>
<td>(0.60)</td>
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<td>(0.70)</td>
<td>(0.43)</td>
<td>(0.45)</td>
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<table>
<thead>
<tr>
<th>Buy+Sell Sum</th>
<th>AUD/USD</th>
<th>CAD/USD</th>
<th>EUR/USD</th>
<th>JPY/USD</th>
<th>GBP/USD</th>
<th>Average Δ in FX rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-5.73</td>
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<td>-7.76</td>
<td>-6.70</td>
<td>-3.54</td>
<td>-5.98</td>
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<td>(0.12)</td>
<td>(0.01)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.12)</td>
<td>(0.00)</td>
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<tr>
<td>Control Sum</td>
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<td>EUR/USD</td>
<td>JPY/USD</td>
<td>GBP/USD</td>
<td>Average Δ in FX rate</td>
</tr>
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<td>-1.98</td>
<td>1.49</td>
<td>-6.14</td>
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<td>(0.03)</td>
<td>(0.45)</td>
<td>(0.63)</td>
<td>(0.04)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>All Event Sum</td>
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<td>CAD/USD</td>
<td>EUR/USD</td>
<td>JPY/USD</td>
<td>GBP/USD</td>
<td>Average Δ in FX rate</td>
</tr>
<tr>
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<td>-13.00</td>
<td>-9.74</td>
<td>-5.20</td>
<td>-9.68</td>
<td>-10.15</td>
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<tr>
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<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.19)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
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</table>

Notes: The table shows one-day exchange rate (FX per USD) changes in percentage points around 8 LSAP news events and 13 FOMC control events, as well as sums over those event window sets. The “p-values” in parentheses below the yield changes show the proportions of n-day changes from July 2007 through January 2010 that were larger in absolute value than the actual change in the n-day period around the event. The 13 control events consist of all FOMC meeting statements and minutes releases from November 2008 through January 2009 that are not “buy” or “sell” events.
Figure 1a: Federal Reserve Bank Assets

NOTE: “Lending to Financial Firms and Markets” includes repurchase agreements, term auction credit, the CPFF, central bank liquidity swaps, money market investor funding facility, other loans, and the Term Asset-Backed Securities Loan Facility (TALF). “Rescue Operations” includes net portfolio holdings of Maiden Lanes I, II, and III and preferred interests in AIA Aurora and ALICO Holdings. The figure shows the accumulation of agency and MBS holdings on the Fed balance sheet beginning in November 2008 and long-term Treasury securities beginning in March 2009.

Notes: The liabilities include “Notes,” i.e., Federal Reserve notes, “Reverse Repurchase Agreements,” i.e., money borrowed in the course of repos, “Reserves of Depository Institutions,” “U.S. Treasury Deposits,” “the U.S. Treasury Supplementary Financial Account,” and “other” liabilities.

SOURCE: Federal Reserve Board.