An Analysis of the Literature on International Unconventional Monetary Policy

Saroj Bhattarai
and
Christopher J. Neely

Working Paper 2016-021C
https://doi.org/10.20955/wp.2016.021

October 2018

The views expressed are those of the individual authors and do not necessarily reflect official positions of the Federal Reserve Bank of St. Louis, the Federal Reserve System, or the Board of Governors.

Federal Reserve Bank of St. Louis Working Papers are preliminary materials circulated to stimulate discussion and critical comment. References in publications to Federal Reserve Bank of St. Louis Working Papers (other than an acknowledgment that the writer has had access to unpublished material) should be cleared with the author or authors.
An Analysis of the Literature on International Unconventional Monetary Policy

Saroj Bhattarai

Christopher J. Neely*

October 31, 2018

Abstract: This paper critically evaluates the literature on international unconventional monetary policies. We begin by reviewing the theories of how such heterogeneous policies could work. Empirically, event studies provide compelling evidence that international asset purchase announcements have strongly influenced international bond yields, exchange rates, and equity prices in the desired manner and curtailed market perceptions of extreme events. Calibrated modeling and vector autoregressive (VAR) exercises imply that these policies significantly improved macroeconomic outcomes, raising output and prices. Central bankers give a measured, positive assessment to most unconventional monetary policy. Despite qualified successes, we recommend that central banks reserve these policies for financial crises and/or times when the zero bound constrains conventional monetary policy.

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

JEL Codes: G12, 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 a Vice President and economist at the Federal Reserve Bank of St. Louis. The authors thank the following individuals for helpful comments or personal communications: Jim Bullard, Miguel Faria-e-Castro, Marco Di Maggio, Joe Gagnon, Magdalena Grothe, Jane Ihrig, Mike Joyce, Leo Krippner, Marco Lo Duca, Matt Raskin, Matt Rognlie, Bern Schwaab, Olivier Vergote and Chris Waller. The authors thank Torsten Slok of Deutsche Bank for data and the following individuals for excellent research assistance: Evan Karson, Joe McGillicuddy, Cooper Howes, Byungjae Kim, Tom Niklas Kroner, and Choongryul Yang. 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.
Table of Contents

1. Introduction ...................................................................................................................... 1

2. Theoretical Frameworks................................................................................................... 6
   2.1 Ineffectiveness of quantitative easing....................................................................... 7
      2.1.1 A general equilibrium model............................................................................. 7
      2.1.2 No role of quantitative easing............................................................................ 9
      2.1.3 Discussion........................................................................................................ 10
   2.2 Models of effective quantitative easing .................................................................. 11
      2.2.1 Exogenous participation constraints in financial markets ............................... 11
      2.2.2 Limits to arbitrage due to leverage constraints................................................ 13
      2.2.3 Signaling channel under time-consistent policy .............................................. 17
      2.2.4 Other models.................................................................................................... 21
   2.3 Forward guidance.................................................................................................... 22
   2.4 Negative deposit rates ............................................................................................. 24

3. A Short History of Modern Unconventional Monetary Policy ...................................... 25
   3.1 The BOJ in 1999-2006............................................................................................ 26
   3.2 The Fed’s LOLR lending to asset purchases .......................................................... 26
   3.3 The BOE’s Asset Purchase Facility (APF)............................................................... 28
   3.4 The ECB responds to the debt crisis with SMP/OMT ............................................ 29
   3.5 Banking support programs...................................................................................... 29
   3.6 The BOJ gets serious in 2013-2018........................................................................ 31
   3.7 The ECB responds to deflation fears ...................................................................... 32
   3.8 The BOJ and BOE react to Brexit.......................................................................... 34
   3.9 The BOJ yield curve targeting................................................................................ 34
   3.10 Fed, ECB and BOE normalization.......................................................................... 35
   3.11 Central bank evaluations of the UMP..................................................................... 36

4. Unconventional Policy Effects on Financial Markets.................................................... 37
   4.1 Event study methodology ....................................................................................... 37
   4.2 Methods to assess channels of monetary policy ..................................................... 41
   4.3 The Pre-crisis literature on UMP ............................................................................ 43
   4.4 The BOJ’s forward guidance and quantitative easing: 1999-2006......................... 44
| 4.5 | Federal Reserve and Bank of England asset purchases ................................................. 47 |
| 4.5.1 | U.S. Treasury, housing and corporate bonds ................................................................. 47 |
| 4.5.2 | Local Supply Effects ...................................................................................................... 49 |
| 4.5.3 | Housing bonds ............................................................................................................. 52 |
| 4.5.4 | Corporate bonds ......................................................................................................... 54 |
| 4.5.5 | Equities and equity uncertainty .................................................................................... 55 |
| 4.5.6 | Time variation in asset purchase effectiveness .............................................................. 57 |
| 4.5.7 | International bond yields ............................................................................................. 58 |
| 4.5.8 | Inferring monetary information from multiple assets .................................................... 60 |
| 4.5.9 | International portfolio flows ......................................................................................... 62 |
| 4.5.10 | Term structure models ................................................................................................. 63 |
| 4.5.11 | Shadow rate studies .................................................................................................... 64 |
| 4.5.12 | Emerging market effects .............................................................................................. 65 |
| 4.5.13 | Dynamic announcement impact .................................................................................... 65 |
| 4.5.14 | Deficits, the maturity of the U.S. debt and yields ........................................................... 66 |
| 4.5.15 | Quantity of debt regression studies .............................................................................. 67 |
| 4.5.16 | Regression studies of the MBS purchase programs ....................................................... 69 |
| 4.5.17 | Regression analysis of corporate credit risk ................................................................ 70 |
| 4.5.18 | Segmented markets analysis ......................................................................................... 70 |
| 4.6 | Fed and BOE support for bank lending ...................................................................... 71 |
| 4.7 | Fed remittances to the Treasury .................................................................................. 73 |
| 4.8 | Forward guidance ......................................................................................................... 74 |
| 4.9 | ECB support for bank lending ..................................................................................... 76 |
| 4.10 | ECB asset purchases: CBPP, SMP/OMT, and APP ......................................................... 78 |
| 4.10.1 | The ECB CBPP ........................................................................................................... 78 |
| 4.10.2 | The ECB SMP and OMT ............................................................................................. 78 |
| 4.10.3 | The ECB APP ............................................................................................................. 82 |
| 4.11 | SNB asset purchases and the role of reserves ............................................................... 82 |
| 4.12 | Riksbank asset purchases ............................................................................................. 83 |
| 4.13 | Financial institutions ................................................................................................. 84 |
| 4.14 | Negative interest rates ............................................................................................... 86 |
1. Introduction

- “Well, the problem with QE is it works in practice, but it doesn't work in theory. … So we did the right thing, I hope.” — Ben Bernanke (Bernanke 2014)

The financial crisis of 2007-2009 produced extreme credit market disturbances and severe downturns in real activity that prompted central banks to implement a variety of policies — emergency lending, conventional and unconventional monetary policy (UMP) — to first stabilize their economies and later to stimulate growth. One might distinguish emergency lending from monetary policy in that the former is narrowly focused on a particular firm or small segment while the latter widely influences interest rates and the overall availability of credit. Central banks typically execute conventional monetary policy through communications and money market transactions that strongly influence short-term interest rates. UMPs, in contrast, apply or extend conventional monetary policy tools to influence monetary and credit conditions through medium- and/or long-term rates or by setting negative deposit rates or by facilitating/subsidizing transactions in specific credit markets, such as those for bank funding or commercial paper.

UMPs are heterogeneous and can encompass many sorts of policies but the most important UMPs have been central bank communication (i.e., “forward guidance”) and/or asset purchases. Internationally, many central banks, most notably the Federal Reserve (Fed), the Bank of England (BOE), the European Central Bank (ECB), the Bank of Japan (BOJ), the Swiss National Bank (SNB), the Riksbank and the Danish National Bank (DNB) have employed a variety of UMP. Neely and Karson (forthcoming) review the modern history of UMP programs.

The success or failure of UMP is a critically important topic because monetary policy has become the main tool of discretionary stabilization policy. It can be implemented faster and more flexibly than can discretionary fiscal policy.\(^1\) For example, although the magnitude of the Great Recession was largely understood in the autumn of 2008, the post-crisis fiscal stimulus bill, the American Recovery and Reinvestment Act (ARRA) of 2009, did not become law until February 2009 and only about half of the $787 billion allocated was actually spent during 2009-2010.

Although some central banks have moved back toward conventional policies, UMP will likely remain an important contingent tool in an era of low inflation, low growth, and low interest rates because the effective lower bound (ELB) on interest rates can hinder a conventional monetary policy response to downturns (Laubach and Williams 2016).\(^2\) Lacking the use of conventional tools near the zero bound, central banks around the world have used UMP to reduce

---

\(^1\) Automatic fiscal stabilizers function quickly but are generally thought to be insufficient, by themselves, for macro stabilization.

\(^2\) This paper usually uses the term ELB, rather than zero lower bound, because the former term has become more popular as central banks have pushed deposit rates into negative territory. At times, however, we use the term zero lower bound when we specifically mean zero.
long yields, raise stock prices, and ultimately increase economic activity and goods prices. The abortive attempts of the Riksbank and the ECB to normalize policy 2-3 years after the financial crisis by raising policy rates, only to lower them again and turn to unconventional asset purchases, demonstrated that central banks must keep UMPs in their toolkit, even when they think they have escaped the ELB. Policymakers agree that UMPs have been crucial tools and that they will likely remain tools of stabilization policy for the foreseeable future:

- “For seven years, in the face of severe headwinds to growth, monetary policy has been the only game in town. … Given constraints on how low nominal interest rates could go, the Bank of England’s MPC had to buy gilts — so-called Quantitative Easing (QE).” — Mark Carney (Carney 2016)

- “[F]or several years, the Fed has been close to being ‘the only game in town,’ as Mohamed El-Erian described it in his recent book.” — Stanley Fischer (Fischer 2014)

In short, UMPs have been heavily used and are likely here to stay but most economists and financial market participants do not fully understand how they might work and what research says about their impact. Our paper will seek to correct this deficiency by laying out the theory of the effect of UMP and then selectively synthesizing and evaluating the sizable and growing literature about how UMPs affect financial markets and the macroeconomy.

As researchers, we strive to evaluate the theoretical and empirical evidence fairly and objectively, with open minds. Some researchers will doubtless dispute some of our interpretations of the literature and may come to different conclusions or simply emphasize the uncertainty associated with inference. There are ample grounds for disagreement over many claims in the literature. We believe, however, that our synthesis represents a thorough and even-handed summary of the state of knowledge on the international use of UMP.

To understand how UMP could work, we first review the theories of financial and macroeconomic effects of such policies. We then present a short history of modern UMP by the four major central banks before evaluating the empirical literature on the effects of UMP on both financial markets and the real economy. Although we cover a great deal of research in many subfields, we still must be very selective in covering a huge and still rapidly growing literature. We review papers that provided either an important methodological or substantive contribution to the understanding of UMP or illustrated methodological problems. We must necessarily omit discussion of some worthy papers with useful contributions.

We present a unified stochastic-discount factor framework to rationalize how the heterogeneous set of UMPs might work. We first show why central bank bond purchases are ineffective in the traditional, plain-vanilla model before laying out a series of modifications proposed by various groups of researchers to rationalize nominal and real effects for such transactions. These mechanisms include participation constraints/incomplete market
participation, limits-to-arbitrage due to leverage effects, signaling effects under time-consistent
policy and reduction of credit spreads. We follow the asset-purchase models with theoretical
frameworks that rationalize forward guidance and negative interest rates.

When considering the empirical evaluation of UMP on financial markets, one must first
recognize that UMPs are varied, comprising broad-based asset purchases and forward guidance
to reduce medium and long yields, targeted asset purchases to ease credit conditions in particular
markets, conditional lending programs to support bank lending and negative interest rates. Even
within categories, seemingly modest differences in how the program was executed or the
economic circumstances can influence the impact of the program. For example, some research
has argued that the Fed’s choice of assets to purchase differentially affected bank lending or
equity market reactions. Similarly, policy impact has often also depended on economic
conditions. The initial Fed asset purchases, for example, did not influence international portfolio
flows in the same manner as similar later policies, presumably because risk tolerance was higher
during the later programs. In short, the efficacy of UMP may depend on the details of the policy
and the economic conditions. With that caveat in mind, we briefly and broadly presage the
findings of the empirical literature.

Asset purchases have been the most important UMP and also among the most thoroughly
researched. Although researchers have investigated such purchases in several ways, event studies
have provided the strongest evidence about their effect on asset prices. Fortunately, the novelty
of the first QE programs by the Fed and BOE (QE1) have allowed researchers to plausibly argue
that all important changes in expectations about QE1 occurred in a small set of events related to
monetary communications. This allowed those researchers to estimate the effect of a given
quantity of asset purchases from the reactions to those events.

Asset purchase programs should have almost all of their effects when market expectations
change. For initial programs, in which a lump sum of purchases was announced, event studies
have shown that most effects occurred at the initial announcement. Large purchases of long-term
bonds, such as those made by the Fed and BOE, strongly influenced yields through several
channels: local supply, duration, and signaling. Bond purchase effects spilled over across
markets, affecting the prices of all sorts of bonds, foreign exchange, commodities, equity and
even tail risk. Later research showed that the type of asset purchased mattered for bank lending.
By improving firm and bank balance sheets and overall confidence, broad-based bond purchases
reduced market measures of default and tail risk. In response to such purchases, financial
institutions rebalanced their portfolios toward higher-yielding corporate bonds but not equities.

Central banks frequently accompanied broad asset purchase announcements with forward
guidance that indicated that short rates would be kept lower for longer than previously expected.
Less research has explicitly focused on forward guidance and its effects are often conflated with
those of simultaneously announced asset purchase programs. Research indicates that forward
guidance can contain information about both a central bank’s reaction function and its view of
the real economy. Because forward guidance works by shifting market expectations, the same announcement can have radically different effects, or no effects, depending on preexisting expectations.

While the Fed and BOE employed broad asset purchases to stimulate the economy, the ECB initially employed more targeted purchases, such as the Securities Markets Programme (SMP), Outright Monetary Transactions (OMT) or Covered Bond Purchase Program (CBPP), to improve functioning or reduce rates in specific markets. These purchases generally reduced the targeted yield or spread and often spilled over to related markets. For example, SMP purchases reduced both sovereign and covered bond yields and improved bank capitalization.

In addition to asset purchase programs, central banks took unconventional action to stimulate bank lending. In the post-crisis period, the BOE, the BOJ and the ECB broke new ground with conditional lending programs, which make the terms (price or quantity) of loans to banks contingent on the bank’s increase in loans to the private sector. Such programs normalized lending conditions, reduced spreads and even produced cross-market spillovers.

Conventional monetary policy utilizes short-term interest rates above the zero bound. The ECB, the BOJ and several smaller central banks broke the zero bound by setting negative deposit rates on reserves. The literature indicates that these negative rates had modest impact and generally did not pass through to retail deposit rates. Negative rates may have, however, negatively affected the profitability of some financial firms.

In addition to studying the effects of UMP on financial markets, researchers have also developed a smaller but rapidly expanding literature on the macro effects of UMP. This literature primarily has studied the effects of asset purchases with DSGE models and structural vector autoregressions (SVARs).

DSGE models have employed a variety of theoretical mechanisms by which central bank long bond purchases can affect the macro economy. Researchers have simulated the impact of such mechanisms with calibrated DSGE models that feature a role for such purchases to affect asset prices and real variables, often disciplining the calibration using results from the empirical literature on effects of unconventional bond purchases on financial markets.

Other empirical researchers have used SVARs with both contemporaneous and sign restrictions to infer the macro impact of UMP, particularly asset purchase programs. These papers suggest that unconventional policy has significantly affected macro variables, such as output and inflation.

Central banks have evaluated both their own and other central banks’ monetary policies. Broadly speaking, central bankers report positive results for asset purchases and bank lending programs. Central bankers see clear evidence that asset purchase programs and other UMP influenced asset prices in the desired direction and judge that there have very likely been
corresponding, desired effects on the macro economy. Nevertheless, central bankers also readily acknowledge that UMP is not a panacea, merely a tool to avoid the worst consequences of negative shocks and obtain moderately better outcomes. One notable shortcoming has been the inability of the BOJ to raise inflation to the 2 percent target, despite many years of efforts and numerous programs.

Neither have the literature’s evaluations of the UMP programs been wholly positive. The magnitude and reach of the UMP programs into financial markets and the real economy almost guarantees that they have produced unintended negative consequences, either in the aggregate or in terms of distributional effects. Some of these consequences may have been unanticipated while others were reasonably anticipated and accepted as part of a package with good overall effects. For example, ECB asset purchases that supported sovereign bond markets also transferred risk between euro area economies and led to increased debt through their effects on incentives. A related program probably also helped recapitalize banks by boosting sovereign bond prices but it appears that this effort was at least partly counterproductive in that it led to inappropriate lending to low-quality borrowers and negative effects in the borrowers’ industries. Similarly, the BOE’s incentive schemes to boost domestic bank lending may have skewed incentives and unintentionally reduced international lending.

Despite the apparent broad success of UMP, several serious questions remain and many of these questions focus on the effects of the broad asset purchase programs. Substantial uncertainty about the size and persistence of UMP effects on asset prices remains. Some of this uncertainty is due purely to sampling variation in the data. Some is due to methodological uncertainty, such as the proper composition of the event set for an event study. Some researchers have argued that UMP effects were transient, mostly disappearing over 6 months. Another line of criticism asks if later UMP policy programs had less impact than the initial programs. We interpret the evidence to support the ideas that although there is significant uncertainty as to the exact size and duration of broad asset purchase effects, there were almost certainly very substantial effects on yields that persisted for many months or years and that the effects of earlier and later programs on yields were likely similar.

In summary, we interpret the literature on UMP to indicate that central banks have developed a number of useful tools to stimulate the economy when the ELB constrains the principal conventional monetary tool, the short-term interest rate. These new tools do present some practical difficulties. For example, central bank purchases of long-term bonds can work at cross purposes with Treasury efforts to manage national debt effectively, making coordination between the central bank and Treasury desirable. Similarly, negative interest rates can create particular problems for financial firms. Because UMP is useful at the ELB but can create particular problems and distortions, we recommend that central banks normally conduct monetary policy by conventional methods — i.e., influencing short-term interest rates by transacting in money markets — and reserve UMP for times when interest rates near the lower bound and/or financial markets require special intervention.
Section 2 reviews types of UMP and rationalizes how these policies might affect asset prices and the larger economy. Section 3 describes the recent history of UMP by the four major central banks. Section 4 describes the empirical literature characterizing the effect of UMP on financial markets while Section 5 documents the analogous empirical literature on UMP effects on the macroeconomy. Section 6 summarizes and discusses our views on future policy and research.

2. Theoretical Frameworks

We present now a theoretical discussion of different channels of unconventional monetary policy. As unconventional monetary policy is heterogeneous, both in models and in practice, we will consider a general, stochastic-discount factor framework that is useful to provide an understanding of various theoretical mechanisms as well as to evaluate various policies. As unconventional monetary policy is often associated with quantitative easing, we will first use a general equilibrium asset pricing model with monetary policy to explain why quantitative easing does not have an effect in standard settings. We will then present various extensions of the basic framework that have been proposed in the literature to provide a theoretical underpinning of quantitative easing. In particular, we first show how quantitative easing can be effective, then we consider extensions to rationalize forward guidance and negative interest rates.

In standard general equilibrium macroeconomic models, quantitative easing is ineffective or neutral. A canonical asset pricing condition provides a useful framework to think about how quantitative easing can affect macroeconomic variables

\[ E_t [A_{t,t+1}(R_{L,t+1} - R_{t+1})] = 0, \]  

(1)

where \( A_{t,t+1} \) is the stochastic discount factor (typically the growth rate in marginal utility of consumption), \( R_{L,t+1} \) is the return on long-term bonds (or other assets such as capital), and \( R_{t+1} \) is the return on short-term bonds (the nominal short-term return is the monetary policy instrument in standard models). (1) holds generally, as long as there are no arbitrage opportunities. It is often called a no-arbitrage condition for that reason. In particular, markets need not be complete for (1) to hold. That is, even though a complete set of state contingent securities for trade might not exist in the model, without any participation constraints, financial frictions, or market segmentation, (1) will still hold. In such a case, quantitative easing is effective only through the signaling channel in standard general equilibrium models.\(^3\) For other channels to be at work, this no-arbitrage condition has to be broken in a non-trivial way, as we show in this section.

To further understand the theoretical literature on effectiveness of quantitative easing, it is useful first to see more precisely how quantitative easing is ineffective or neutral in standard

\(^3\) Woodford (2012) contains more detailed discussion along these lines.
models. We therefore, begin this section with first showing the neutrality of quantitative easing in a standard general equilibrium set-up and then discussing how the literature has modeled different channels of quantitative easing.

2.1 Ineffectiveness of quantitative easing

Wallace (1981) first showed a neutrality result for central bank balance sheet policies. We undertake such an analysis here in a self-contained way.

2.1.1 A general equilibrium model

We consider a simple general equilibrium model. A representative household maximizes

\[ E_0 \sum_{t=0}^{\infty} \beta^t U (c_t, h_t), \]

where \( 0 < \beta < 1 \) is the discount factor, \( c_t \) is household consumption, and \( h_t \) is hours supplied by the household. \( E_0 \) is the mathematical expectation operator conditional on period-0 information and \( U(c_t, h_t) \), the period utility, is increasing in \( c_t \) and decreasing in \( h_t \). The household’s flow budget constraint (in real terms) is then given by

\[ b^H_{1,t-1} \Pi_{t-1}^{-1} + Q_{1t} b^H_{2,t-1} \Pi_{t-1}^{-1} + l^H_{1,t-1} \Pi_{t-1}^{-1} = Q_{1t} b^H_{1,t} + Q_{2t} b^H_{2,t} + Q_{1t} l^H_{1,t} + c_t - w_t h_t - \varphi_t + \tau_t, \]

where \( b^H_{1,t} = \frac{B^H_{1,t}}{P_t} \) with \( B^H_{1,t} \) the nominal one-period Treasury bond held by the household and \( b^H_{2,t} = \frac{B^H_{2,t}}{P_t} \) with \( B^H_{2,t} \) the nominal two-period Treasury bond held by the household. Moreover, \( l^H_{1,t} = \frac{l^H_{1,t}}{P_t} \) with \( l^H_{1,t} \) the nominal one-period Central bank bond/reserves held by the household. Here, \( \Pi_t = \frac{P_t}{P_{t-1}} \) is gross inflation with \( P_t \) the price level, \( Q_{1t} \) is the price of the one-period government bond, and \( Q_{2t} \) is the price of the two-period government bond. Moreover, \( w_t \) is real wages, \( \varphi_t \) is firm profits, and \( \tau_t \) is (net) lump-sum taxes to the Treasury. The household then chooses \( \{c_t, h_t, b^H_{1,t}, b^H_{2,t}, l^H_{1,t}\}_{t=0}^{\infty} \) to maximize (2), subject to a sequence of budget constraints (3), while taking as exogenously given initial wealth and \( \{\Pi_t, \varphi_t, w_t, Q_{1t}, Q_{2t}, \tau_t\}_{t=0}^{\infty} \).

A representative firm produces output using labor as input

---

4 Eggertsson and Woodford (2003) and Curdia and Woodford (2011) show such a result in general equilibrium models with nominal rigidities.

5 The one-period Treasury bond and the one-period central bank reserves are perfect substitutes. As we discuss later, we model conventional monetary policy as determining the returns on such a one-period nominal bond. Moreover, we do not have fiat money/cash in the model. We also do not introduce the ELB on nominal interest rates as it is not essential for the main point of this section. We will discuss these issues later.

6 The household is also subject to a no-Ponzi game constraint.
\[ y_t = A_t F(h_t), \] (4)

where the production function \( F(h_t) \) is increasing in \( h_t \) and \( A_t \) is a stationary aggregate productivity shock.\(^7\) The firm hires labor in a perfectly competitive factor market and maximizes profits

\[ \psi_t = y_t - w_t h_t. \] (5)

The firm then chooses \( \{h_t\}_{t=0}^{\infty} \) to maximize (5), subject to the production function (4), while taking as exogenously given \( \{w_t, A_t\}_{t=0}^{\infty}. \)\(^8\)

Now we turn to the government. The Treasury, for simplicity, does not spend and keeps constant the total supply of one-period and two-period Treasury bonds. Let \( T_t \) be the remittances it receives from the central bank, which it returns to the household, net of interest expense on debt. The Treasury budget constraint is then

\[ T_t + \tau_t + Q_{1t} b^T_{1,t} + Q_{2t} b^T_{2,t} = b^T_{1,t-1} \Pi_t^{-1} + Q_{1t} b^T_{2,t-1} \Pi_t^{-1}, \] (6)

where \( b^T_{1,t} = \frac{B^T_{1,t}}{p_t} \) with \( B^T_{1,t} \) the nominal one-period Treasury debt and \( b^T_{2,t} = \frac{B^T_{2,t}}{p_t} \) with \( B^T_{2,t} \) the nominal two-period Treasury debt. Note we can then impose the Treasury's debt policy on (6)

\[ B^T_{1,t} = B^T_1, B^T_{2,t} = B^T_2. \] (7)

The central bank faces the flow budget constraint (in real terms) as

\[ Q_{1t} b^C_{1,t} + Q_{2t} b^C_{2,t} - Q_{1t} l^C_{1,t} + T_t = b^C_{1,t-1} \Pi_t^{-1} + Q_{1t} b^C_{2,t-1} \Pi_t^{-1} - l^C_{1,t-1} \Pi_t^{-1}, \] (8)

where \( b^C_{1,t} = \frac{B^C_{1,t}}{p_t} \) with \( B^C_{1,t} \) the nominal one-period Treasury bond held by the central bank and \( b^C_{2,t} = \frac{B^C_{2,t}}{p_t} \) with \( B^C_{2,t} \) the nominal two-period Treasury bond held by the central bank. Moreover, the central bank also issues nominal one-period liabilities, \( l^C_{1,t} \), which capture interest bearing reserves issued by major central banks during the quantitative easing period. Thus, in the flow budget constraint above, \( l^C_{1,t} = \frac{l^C_{1,t}}{p_t}. \)\(^9\)

---

\(^7\) The model does not have capital and physical investment, with no effect on our main point.

\(^8\) For simplicity, we do not introduce nominal rigidities, such that conventional monetary policy has real effects. It is however, very straightforward to extend the set-up to incorporate these features, with no effect on our main point, as we show later.

\(^9\) We do not necessarily need to “consolidate” the two budget constraints (7) and (8) into one single government budget constraint. The interpretation of quantitative easing however, can depend on whether we consolidate the government into one entity or not, as we discuss later.
A simple feedback rule determines the central bank’s short-term interest rate policy, or conventional monetary policy

\[ \beta Q^{-1}_{1t} = \left( \frac{\Pi_t}{\Pi} \right)^{\phi_\pi}, \]  
(9)

where \( \phi_\pi \geq 1 \) is the feedback parameter (which ensures that the rule satisfies the Taylor principle) and \( \Pi \) is the steady-state value of gross inflation.

The focus here is on balance sheet policies of the central bank, which provide a framework for understanding the role of quantitative easing. Let us denote by \( B_{t,t}^C = \frac{Q_{2t}B_{2t}^C}{Q_{1t}B_{1t}^C} \) the ratio of the value of the two assets (two-period and one-period assets) on the central bank’s balance sheet, that is, the composition of the central bank balance sheet. Moreover, the level of central bank’s total reserves \( (L_{1,t}^C) \) is the the size of the balance sheet. Then quantitative easing policies will pertain to either (a) changes in the composition of the central bank’s assets (changes in \( B_{t,t}^C \)) while holding constant the size of the balance sheet constant (no changes in \( L_{1,t}^C \)); or (b) changes in the size of the central bank’s balance sheet (changes in \( L_{1,t}^C \)), while holding constant the composition of the assets (no changes in \( B_{t,t}^C \)).

Finally, the goods and asset market clearing conditions are

\[ y_t = c_t, \]  
(10)

\[ B_{1,t}^H + B_{1,t}^C = B_{1,t}^T, \quad B_{2,t}^H + B_{2,t}^C = B_{2,t}^T = B_{2}^T, \]  
(11)

\[ L_{1,t}^H = L_{1,t}^C. \]  
(12)

2.1.2 No role of quantitative easing

Now we show that central bank balance sheet variables do not determine macroeconomic quantities and prices. The private sector equilibrium conditions are given by

\[ E_t \left[ \frac{\beta u_c(c_{t+1}, h_{t+1})}{u_c(c_t, h_t)} \frac{\Pi_{1,t+1}}{Q_{1,t}} \right] = 1, \]  
(13)

\[ E_t \left[ \frac{\beta u_c(c_{t+1}, h_{t+1})}{u_c(c_t, h_t)} \left( \frac{Q_{2,t+1}\Pi_{2,t+1}}{Q_{2,t}} \frac{\Pi_{2,t+1}}{Q_{2,t}} \right) \right] = 0, \]  
(14)

\[ A_t F_h(h_t) = -\frac{u_h(c_t, h_t)}{u_c(c_t, h_t)}, \]  
(15)

\[ c_t = A_t F(h_t). \]  
(16)
where we impose goods market clearing.\textsuperscript{10} We now add the conventional monetary policy rule

\[ \beta Q_{t+1} = \left( \frac{\Pi}{\Pi} \right)^{\phi_n} \, . \]  

(17)

Returns over the one-period and two-period bonds are

\[ R_{t+1} = \frac{\Pi_{t+1}}{Q_{t,t}} \]  

and

\[ R_{2,t+1} = \frac{Q_{t+1} \Pi_{t+1}}{Q_{2,t}} \]

respectively.

We establish the irrelevance of quantitative easing by recognizing that the equilibrium path of \( \{\Pi_t, Q_{1t}, Q_{2t}, c_t, h_t\}_{t=0}^\infty \) is completely determined by (13)-(17), without a role for either the composition of the central bank's balance sheet \( (B^C) \) or the size of the central bank's balance sheet \( (L^C) \). Note that quantitative easing is not simply neutral for real variables, but crucially it is even neutral for nominal variables such as inflation and nominal bond prices.\textsuperscript{11} In fact, (13), (15)-(17), completely determine the equilibrium path of \( \{\Pi_t, Q_{1t}, c_t, h_t\}_{t=0}^\infty \) and therefore the path of the two-period bond price, \( \{Q_{2t}\}_{t=0}^\infty \), is determined residually using (14), the no arbitrage condition.\textsuperscript{12} Because the two-period bond price can be determined residually and central bank balance sheet variables do not matter for either nominal or real variables, quantitative easing is irrelevant in standard general equilibrium models.

\subsection*{2.1.3 Discussion}

We now discuss the most important features and caveats that render quantitative easing ineffective in the above set-up. As mentioned before, Chen, Curdia, and Ferrero (2012), Gertler and Karadi (2011, 2013), and Gertler and Kiyotaki (2010), introduce a role for quantitative easing by breaking (14) with exogenous market participation constraints and/or financial frictions that lead to leverage constraints. Such frictions are necessary, but not sufficient and need to be coupled with an ability of the government to directly/indirectly mitigate these frictions or affect the term-premium.

\textsuperscript{10} In addition to the first-order necessary conditions, a necessary optimality condition also includes a standard transversality condition. The optimality conditions have the usual interpretation. (13) is a Euler equation, (14) determines the price of the two-period bond, and (15) equates the marginal product of labor with the marginal rate of substitution between consumption and leisure. Note that (14) provides a specific formulation for the stochastic discount factor \( \Lambda_{c,t+1} = \frac{\tilde{B}U(c_{t+1}, h_{t+1})}{U(c_t, h_t)} \) compared to our general presentation in (1). Moreover, (14) provides specific formula for the one-period and two-period bond returns. Finally, while we do not need to assume preference and technology functional forms, the standard formulations of

\[ U(c_t, h_t) = \log c_t - \frac{1}{1+\phi} h_t^{1+\phi} \]  

and

\[ F(h_t) = h_t^{\alpha} \]

give \( U_c(c_t, h_t) = c_t^{-1} \), \( U_h(c_t, h_t) = -h_t^\phi \), and \( F'_h(h_t) = \alpha h_t^{\alpha-1} \).

\textsuperscript{11} If the model included sticky prices, such that conventional monetary policy had real effects, unconventional monetary policy would still be neutral, both for nominal and real variables. With sticky prices, (15) would be replaced by a standard Phillips curve, but nothing else in terms of the claims made above would change. We consider the extension with nominal rigidities later.

\textsuperscript{12} Due to the neutrality of real variables, (15) and (16) determine \( \{c_t, h_t\}_{t=0}^\infty \).
But even with (14) holding, there could be a role for expansion in the central bank balance sheet by injecting reserves, $L^C_{tt}$, if reserves played a special role, above and beyond pecuniary returns. Here, central bank reserves and short-term bonds are perfect substitutes and such a possibility does not arise. If we had modeled central bank liabilities as non-interest bearing assets (say cash), and allowed them a role in facilitating transactions, then the size of the central bank balance sheet can matter (as in Auerbach and Obstfeld 2005). At the same time, however, if the opportunity cost of holding such central bank liabilities were zero (this can happen when the economy is completely satiated with cash), such as at the ELB, then quantitative easing would have no effect. If the expansion in central bank balance sheet driven by printing cash were to continue indefinitely, even after interest rates are positive, then such a policy would not be neutral for usual reasons.

We have modeled the Treasury policy in a simple way that can be generalized. The key is that the Treasury keeps government debt dynamics sustainable through appropriate tax changes, not necessarily that it fixes the supply of Treasury bonds. Additionally, while we have presented separate Treasury and central bank budget constraints, in principle, they can be consolidated into one single government budget constraint, but the interpretation of quantitative easing differs according to the precise choices made and the assumptions that underlie such a consolidation.

One critical part of the irrelevance result above is that conventional policy, as given by (17), independently determines the path of inflation by varying the short-term nominal interest rate and respecting the Taylor principle. In particular, there is no link between the central bank's balance sheet evaluation and its choice of the path of the short-term interest rate. If there is such a link however, then even with (14) holding, quantitative easing can affect macroeconomic prices and quantities, as the path of the short-term interest rate can change. We will discuss this signaling channel of quantitative easing modeled in Bhattarai, Eggertsson, and Gafarov (2015) later in detail.

2.2 Models of effective quantitative easing

We now discuss various models of quantitative easing in the literature.\(^{13}\)

2.2.1 Exogenous participation constraints in financial markets

Chen, Curdia, and Ferrero (2012) introduce exogenous participation constraints, building on preferred habitat theory. In particular, some agents can trade in both long-term and short-term bonds, subject to a transaction cost, while other agents can trade only in long-term bonds.

\(^{13}\) We will again abstract from the issue of a binding ELB on nominal interest rates as the models to be discussed below contain mechanisms that work even at positive interest rates. Moreover, we will continue to eschew nominal rigidities as again they are not central to the new mechanisms. For this reason, we will not emphasize the distinction between nominal and real interest rates and bond prices in the following sub-sections. We will extend the model with both these features in the next section.
Without loss of generality, let's again suppose the long-term bonds are two-period bonds. In such a case, the no-arbitrage asset pricing condition of the type (1) or (14) only applies to the unrestricted segment of the population

\[ E_t \left[ \Lambda_{t,t+1}^U \left( \frac{R_{2,t+1}}{\gamma_t} - R_{t+1} \right) \right] = 0, \]  

(18)

where \( \Lambda_{t,t+1}^U \) is the stochastic discount factor of the unrestricted type and \( \gamma_t \) is the transaction cost of participating in both markets. Given the exogenous market segmentation, the Euler equation of the restricted segment of the population is defined only for long-term bonds and is

\[ E_t \left[ \Lambda_{t,t+1}^R R_{2,t+1} \right] = 1, \]  

(19)

where \( \Lambda_{t,t+1}^R \) is the stochastic discount factor of the restricted type.

The transaction cost plays an important role in the analysis; just exogenous market segmentation alone would not produce Chen, Curdia, and Ferrero (2012)'s results. A linear-approximation illustrates this point. Without transaction cost, (18) above (after linearization), would have no risk/term premium, as it is

\[ E_t [R_{2,t+1} - R_{t+1}] = 0 \quad \text{or} \quad Q_{2,t} = Q_{1,t} + E_t Q_{1,t+1}, \]

which is simply the expectations hypothesis: the two-period bond price is the sum of the one-period bond price today and the expected one-period bond price next period. With the transaction cost, the term premium exists and is a function of the transaction costs. With the transaction cost, (18) above (after linearization) gives,

\[ E_t [R_{2,t+1} - R_{t+1}] = \gamma_t, \]  

(20)

or,

\[ Q_{2,t} = Q_{1,t} + E_t Q_{1,t+1} - \gamma_t. \]

Chen, Curdia, and Ferrero (2012) directly assume that the transaction cost is a negative function of the ratio of central bank holdings of two-period bonds to one-period bonds. That is, they assume that \( \gamma_t \equiv \gamma(B_{R,t}^C), \) where \( \gamma(.) \) is decreasing. Central bank purchases of long-term bonds increase \( B_{R,t}^C \) and thereby reduce transaction costs \( \gamma_t \), and the term-premium.

Government purchases of long-term bonds affecting the term-premium do not suffice however, to produce macroeconomic effects. Without exogenous market segmentation/participation constraints, only (18) would hold (there would be no separate Euler

\[ \text{To allow a portfolio balance channel, some other papers, in a less micro-founded approach, directly introduce long-term bonds in utility function of agents or assume an aggregator in preferences that directly embodies imperfect substitution between long-term and short-term bonds. See for instance, Harrison (2012) and Alpanda and Kabaca (2016).} \]

14
equation (19)), which would then imply that long-term bond prices would adjust to equalize expected returns across the two assets, as in (20). The stochastic discount factor would therefore not adjust/change. That is, as in the simple model above, the equilibrium condition that determines the long-term bond return would still just determine long-term bond prices residually, while the rest of the model equilibrium is independently determined.

In the presence of market segmentation and a transaction cost, quantitative easing would change long-term yields and produce macroeconomic effects. The key reason is that (19) becomes part of the model equilibrium. For (19) to hold, the stochastic discount factor of the restricted households must change. That is, after linearization (19) is

\[ E_t[A_{t,t+1}^R] = -E_t[R_{2,t+1}], \]

and if \( R_{2,t+1} \) changes, then \( A_{t,t+1}^R \) will change, along with restricted households consumption. In general equilibrium then, central bank purchases of long-term bonds will change macroeconomic quantities and prices.

2.2.2 Limits to arbitrage due to leverage constraints

Gertler and Karadi (2011, 2013) and Gertler and Kiyotaki (2010) introduce financial frictions, in particular, the possibility of binding leverage constraints on financial intermediaries. A general version of the non-arbitrage relation (1) holds in their model, where the rate of return \( r^{+,t+1} \) is for capital,

\[ E_t[A_{t,t+1}(r_{L,t+1} - r_{t+1})] \geq 0. \]  

(21)

When leverage constraints bind for financial intermediaries, their inability to increase borrowing/leverage means that (21) holds with a strict inequality

\[ E_t[A_{t,t+1}(r_{L,t+1} - r_{t+1})] > 0. \]  

(22)

The difference between the (risk-adjusted) returns on long-term assets (capital) and the risk-free asset (say, one-period government bond) in (22) above, is called the external finance premium in models with financial frictions. In particular, even with a linear approximation, the expected return on long-term assets (capital) and short-term bonds is not equalized and excess returns/spread arise in equilibrium.\(^{15}\)

The key friction in the models of Gertler and Karadi (2011, 2013) and Gertler and Kiyotaki (2010) is that financial intermediaries, which intermediate funds between households and non-financial firms, can abscond with funds. The balance sheet of banks consists of their assets,
which are claims on capital $K_t$ of non-financial firms with the price of capital $S_t$, liability, which is (one-period, risk-free) borrowing from households $B_{1,t}$, and net worth $NW_t$. Thus, we have

$$S_tK_t = NW_t + Q_{1,t}B_{1,t},$$

with the flow constraint of financial intermediaries given by

$$NW_{t+1} = R_{L,t+1}S_tK_t - B_{1,t} = R_{t+1}NW_t + (R_{L,t+1} - R_{t+1})S_tK_t,$$

as net worth evolves over time via retained earnings, where $R_{L,t+1}$ is the return on capital. Let $V_t$ be the value maximized by banks, the expected terminal value of net worth, given the random bank exit rate, $\theta$.\(^{16}\) As the banks can abscond with a fraction, $\lambda$, of its assets, the incentive constraint is

$$V_t \geq \lambda S_tK_t.$$

The banks then maximize $V_t$ subject to the flow constraint (24) and the incentive constraint (25).\(^{17}\) If the incentive constraint (25) binds (alternately, if the Lagrange multiplier on the incentive constraint (25) is strictly positive), it is possible to show that the following leverage constraint holds with equality:

$$S_tK_t = \varphi_t NW_t,$$

where the leverage ratio, $\varphi_t$, is endogenously and optimally determined.\(^{18}\) How is $\varphi_t$ determined? In equilibrium, we can write $V_t$ as a linear function of $S_tK_t$ and $NW_t$: $V_t = v_tS_tK_t + \eta NW_t$. Here, $v_t$ is the discounted gain of expanding capital by one unit, holding net worth (that is, the marginal value of bank's capital) while $\eta_t$ is the discounted gain of expanding net worth by one unit, holding capital constant (that is the marginal value of bank's net worth). Then, it follows that when (25) holds with equality, we have $\varphi_t \equiv \frac{\eta_t}{\lambda - v_t}$. Moreover, let $\xi_t$ be the Lagrange multiplier on the incentive constraint (25). Then, it additionally follows that $v_t = \frac{\lambda \xi_t}{1 + \xi_t}$.

\(^{16}\) Formally, in the model, it is given by $V_t = \max(1 - \theta)E_t \sum_{i=0} R^i \Lambda_{t+i+1}NW_{t+i+1}$ where $\theta$ is the random exit rate of banks. The financial friction and the random exit rate means that it is optimal for banks to accumulate net worth until they exit. In the notation above, we drop the bank specific notation for clarity. The aggregate evolution of bank net worth will differ slightly due to entry and exit of banks.

\(^{17}\) The maximization problem can be written recursively as $V_t = \max E_t \left\{ \Lambda_{t+1} [(1 - \theta)NW_{t+1} + \theta V_{t+1}] \right\}$.

\(^{18}\) Thus, in models without the incentive constraint/financial friction, $v_t = 0$. Another way to see this, is that, given that $v_t$ is the marginal value of capital, it is given by $\frac{\partial V_t}{\partial K_t}$, which gives $v_t = E_t \left\{ \Lambda_{t+1} [(1 - \theta)(R_{L,t+1} - R_{t+1}) + \theta \frac{NW_{t+1}}{NW_t} V_{t+1}] \right\}$ where, without an external finance premium, $v_t$ would be zero.
When the incentive constraint (25) and thereby the leverage constraint (26), bind in the model, limits to arbitrage arises such that there is a positive difference between the expected return on capital and risk free debt in equilibrium. In particular, the external finance premium is

$$E_t[A_{t+1} \theta_{t+1} (R_{L,t+1} - R_{t+1})] = \lambda \frac{\xi_t}{1+\xi_t},$$

(27)

where $\theta_t = (1 - \theta) + \theta \eta_t$. Again, (27) makes clear that when $\xi_t > 0$, the external finance premium exists. Moreover, as the flow constraint (24) makes clear, without binding leverage constraints, the incentives of financial intermediaries would be to borrow an infinite amount if there were a positive external finance premium. Generally, this premium depends inversely on the financial intermediaries’ net worth in the models of Gertler and Karadi (2011, 2013) and Gertler and Kiyotaki (2010). Moreover, net worth of financial intermediaries is a key state variable in the model, which leads to a propagation and feedback mechanism of shocks.\(^\text{19}\)

In situations where leverage constraints on financial intermediaries bind and, in particular, when financial shocks raise the external finance premium, government credit policy can be useful as a countercyclical measure. Gertler and Karadi (2011) model quantitative easing in terms of the central bank engaging directly in financial intermediation. The central bank is less efficient than the private sector in financial intermediation, but is not subject to borrowing/leverage constraints (26). That is, it can raise funds elastically from households by issuing risk-free debt. These funds are then used to finance non-financial firms. Let us separate total intermediation into private and government components

$$K_t = K_{t,p} + K_{t,g},$$

where now $K_{t,p}$ is private sector claims on non-financial firms while $K_{t,g}$ is government claims on non-financial firms. Suppose that the government does $\psi_t$ percent of total financing, with $K_{t,g} = \psi_t K_t$, where $\psi_t$ is a measure of credit policy. The path of $\psi_t$ affects capital accumulation and output, intermediated through its effect on the external finance premium. Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) consider feedback rules of the type

$$\psi_t = YE_t[R_{L,t+1} - R_{t+1}],$$

where $Y > 0$ and show that such policy reduces the external finance premium when negative financial shocks hit the economy. By reducing the external finance premium, that is, the interest

---

\(^{19}\) Brunnermeier and Sannikov (2016) present an alternate model of financial frictions where the net worth of financial intermediaries plays a key role in propagation of shocks. They also consider a central bank policy that consists of short-term interest rate policy coupled with open market operations that keep the ratio of fiat money to outstanding long-term government bonds constant. Such a policy, by recapitalizing the financial intermediaries through long-term bond price changes, helps mitigate the effect of adverse shocks.
rate spread, and with it, the cost of funding/capital, such policy boosts asset prices and consumption/output.

Gertler and Kiyotaki (2010)'s model features the key financial friction in intermediation described above as well as idiosyncratic liquidity/investment shocks across firms/banks.\(^{20}\) This feature permits an analysis of interbank lending and, in particular, how the functioning of the interbank market, which is a wholesale funding source for banks, can impact the effects of financial shocks. Perhaps more importantly, Gertler and Kiyotaki (2013) use the model to analyze two other credit policies used by central banks during the peak of the crisis. First, the central bank can set up liquidity facilities/discount window lending. The discount window lends funds to banks (who as described above, lend funds to non-financial firms). Such a credit policy can have a macroeconomic effect because the central bank is better able to enforce payments and thus the intermediary can only divert \(\lambda'\) fraction of its assets, where \(\lambda' < \lambda\). Second, the central bank can directly inject equity into financial intermediaries. In such credit policy, the government pays an above-market price for claims on the bank. Thus, this policy directly increases the net worth of banks, which helps mitigate the rise of the external finance premium. In this case, banks cannot divert assets financed by equity injections by the government. This again works to increase the value of assets that are intermediated and mitigate the effects of a financial shock.

Gertler and Karadi (2013) extend the setup in Gertler and Karadi (2011) to analyze the effects of central bank purchases of long-term government bonds by allowing the financial intermediaries to also hold long-term government bonds. Again, we will assume that the long-term bonds are two-period bonds. Therefore, the balance sheet (23) and flow constraint (24) become

\[
S_tK_t + Q_{2,t}B_{2,t} = NW_t + Q_{1,t}B_{1,t},
\]

\[
NW_{t+1} = R_{L,t+1}S_tK_t + Q_{1,t+1}B_{2,t} - B_{1,t} =
R_{t+1}NW_t + (R_{L,t+1} - R_{t+1})S_tK_t + (R_{2,t+1} - R_{t+1})Q_{2,t}B_{2,t}.
\]

Next, the incentive constraint (25) is generalized as

\[
V_t \geq \lambda S_tK_t + \kappa Q_{2,t}B_{2,t},
\]

where a bank can run away with a different fraction of its assets depending on whether they are long-term government bonds or claims to capital. As a result, in addition to (27), a similar limits-to-arbitrage condition also holds for long-term government bonds.

\(^{20}\) Firms reside on islands and banks can only lend to firms in their island.
In this extended set-up then, government can issue short-term government bonds and use the proceeds to purchase long-term government bonds, which will bring down interest rate spreads/external finance premium. The reasoning is exactly the same as described above for the simple set-up with credit policy of the government. By comparing (27) with (28), one sees that the following no-arbitrage condition holds

\[ \lambda E_t[A_{t+1} \theta_{t+1} (R_{2,t+1} - R_{t+1})] = \kappa \frac{\bar{a}_t}{1+\bar{a}_t}, \]

which means that government purchases of long-term government bonds reduce both excess returns, the excess of returns to capital over the short rate and the excess of returns to the long rate over the short rate. This boosts up asset prices and increases consumption/output by reducing the cost of funds.

2.2.3 Signaling channel under time-consistent policy

Bhattarai, Eggertsson, and Gafarov (2015) provide a theory for the signaling channel of quantitative easing. The model uses a linear approximation, assumes the expectation hypothesis and transactions costs but has no financial frictions nor participation constraints nor term premium. For simplicity, we assume again that the long-term asset in the model is a two-period bond and a linearized version of (14) again is

\[ Q_{2,t} = Q_{1,t} + E_t Q_{1,t+1}, \]

which again is simply the expectations hypothesis: the two-period bond price is the sum of the one-period bond price today and the expected one-period bond price next period.

How does quantitative easing send a signal about current or future short-term interest rates? First, in the model, expectations about the current and future path of the policy rate are not held fixed or determined. In particular, monetary policy is not modeled via a fully credible state-contingent path of the policy rate that the central bank can ex-ante commit to or through a commitment to a policy rule like (17). It is well-known that state-contingent commitment policy is time-inconsistent. In particular, in standard models, once it is feasible to exit from the ELB situation, the central bank has an incentive to immediately raise the short-term interest rate. The paper therefore considers optimal policy, but optimal time-consistent policy. In such a case, balance sheet policies can have macroeconomic effects by affecting the path of the policy rate. Before detailing the mechanisms, it is useful to consider the simple model above to think through the implications of consolidating the Treasury and central bank budget constraints (6)-(8).

______________

21 Farmer (2012c) also discusses how this feature is key to allow a signaling channel of quantitative easing.
Suppose then that we consolidate the two budget constraints (6)-(8) and consider a single
government entity, with the flow budget constraint given by

\[
Q_{1t}(b_{1,t}^r + l_{1,t}^c - b_{1,t}^c) + Q_{2t}(b_{2,t}^r - b_{2,t}^c) + \tau_t \\
= (b_{1,t-1}^r + l_{1,t-1}^c - b_{1,t-1}^c)\Pi_t^{-1} + (b_{2,t-1}^r - b_{2,t-1}^c)Q_{1t}\Pi_t^{-1},
\]  

(30)

where central bank transfers to the Treasury drop out. Moreover, through market clearing
conditions (11)-(12), it is clear that what appears above in (30) is the bonds in the hands of the
public (central bank and Treasury bonds). From this perspective, central bank policies that either
increase the ratio of long-term bonds in its balance sheet or increase the level of short-term
reserves held by the public, decrease the average maturity of government debt held by the public.
Given this interpretation, one must introduce a channel through which maturity composition of
outstanding government debt matters via its effect on the path of future central bank
(conventional) policy rate. The key step in this, as mentioned above, is to model conventional
monetary policy as being determined optimally and in a time-consistent fashion. In the model,
the government chooses the path of its monetary and fiscal policy instruments, the short-term
interest rate \(\tau_t\), and taxes \(\tau_t\), to maximize household welfare or minimize the
following loss \((L_\tau)\)

\[
L_\tau \equiv \phi_\pi\Pi_t^2 + \phi_y y_t^2 + \phi_\tau\tau_t^2,
\]

(31)

where variations not only in inflation and output (with the weight parameters \(\phi_\pi\) and \(\phi_y\)) are
costly, but also variation in taxes (with weight parameter \(\phi_\tau\)) are costly, as taxation leads to
dead-weight losses in the model. In this set-up, the government faces the constraints (13)-(16)
and (30). Because the government budget constraint affects its optimization problem of
determining the short-term interest rate, unlike the simple model, the evolution of the
consolidated government balance sheet affects the equilibrium of nominal and real variables.

Next, let's consider the case where the two budget constraints remain separate. For reference,
the central bank budget constraint is again, given as

\[
Q_{1t}b_{1,t}^c + Q_{2t}b_{2,t}^c - Q_{1,t}l_{1,t}^c + T_t = b_{1,t-1}^c\Pi_t^{-1} + Q_{1t}b_{2,t-1}^c\Pi_t^{-1} - l_{1,t-1}^c\Pi_t^{-1},
\]

(32)

where \(T_t\) represent transfers to the Treasury and, as mentioned before, the central bank's balance
sheet features a maturity mismatch. That is, central bank liabilities are short-term and interest
bearing while assets are, both short-term and long-term. Increasing the ratio of long-term bonds
in the central bank's portfolio or increasing the level short-term reserves held by the public are

---

22 In the paper, a linearized version of the model is used, which simplifies some further aspects of the analysis.
23 Moreover, to assess at the end the effects of the short-term nominal rate on the real rate and macroeconomic
variables, one needs to augment the model with sticky prices. As that part is not essential to convey the key
intuition, for now, we do not consider this extension.
now distinct policies. The government chooses the path of its conventional policy instrument and transfers to the Treasury, the short-term interest rate \( \{Q_{1t}^{-1}\} \) and \( \{T_t\} \), to maximize household welfare or minimize the following loss \( (L_t) \):

\[
L_t = \phi_\pi \Pi_t^2 + \phi_y y_t^2 + \phi_T T_t^2 .
\]

This objective of smoothing transfers to the Treasury (with weight parameter \( \phi_T \)) can be motivated either as effectively smoothing taxes (as in the consolidated case above) or as simply arising due to political economy considerations.\(^24\) In this set-up, the central bank faces the constraints (13)-(16) and (32).\(^25\) Because the central bank budget constraint affects its optimization problem of determining the short-term interest rate, unlike the simple model, the evolution of the central bank balance sheet affects the equilibrium of nominal and real variables.

Having determined that the evolution of the central bank balance sheet is relevant for equilibrium determination, we must still explain why quantitative easing policies provide the central bank with an incentive to keep short-term interest rates lower than they would be otherwise. We can illustrate the mechanism in both interpretations of quantitative easing.

Let’s consider then, two versions of the consolidated government budget constraint (30). First, suppose that the central bank does not issue one-period reserves and that the government only issues one-period debt, in net. Then, after imposing market-clearing, we get

\[
Q_{1t}(b_{1,t}^H) + \tau_t = b_{1,t-1}^H \Pi_t^{-1} .
\]  

Second, suppose that the government only issues two-period debt, in net. Then, after imposing market-clearing, we get

\[
Q_{2t}(b_{2,t}^H) + \tau_t = (b_{2,t-1}^H)Q_{1t} \Pi_t^{-1} .
\]

Comparing (34) with (35) (which is easiest to see with a linear approximation) shows that the dynamics of government debt and taxes get affected by the short-term interest rate \( -Q_{1t} \) in the first case, but by \( Q_{1t} - Q_{2t} \), which using (29) is equal to \( -E_t Q_{1,t+1} \), in the second case. The mechanism is driven by mean-reverting transition dynamics, such that \( Q_{1t} \) is not equal to \( -E_t Q_{1,t+1} \). In fact, mean-reverting dynamics imply \( E_t Q_{1,t+1} = \rho Q_{1,t} \), with \( \rho < 1 \).\(^26\) When the government engages in quantitative easing and makes the maturity of outstanding debt held by

\(^24\) In this separate central bank case, for Treasury policy it is easiest, but not necessary, to think about it as pursuing a zero debt policy with \( b_1^T = b_2^T = 0 \). Then, we have (6) as \( T_t = -\tau_t \), which makes it especially clear how transfers from the central bank affect household taxes.

\(^25\) In the paper, a linearized version of the model is used, which simplifies some further aspects of the analysis.

\(^26\) The precise expression for the rate of mean reversion depends, in equilibrium, on structural model parameters, and dynamics is driven by the state variable in the model. Moreover, this makes it clear how this signaling mechanism is not in operation for one-time permanent changes in interest rate and is instead based on mean-reverting transition dynamics.
the public shorter, the current short-term interest rate ($-Q_{1,t}$) more directly affects debt and tax dynamics. For one period vs. two period debt, the difference in effects are 1 vs. $\rho < 1$. To smooth taxes, the government then smooths the path of the short-term interest rate.

To see the mechanism in the other interpretation of quantitative easing based on an independent central bank, it is again useful to consider two versions of the central bank budget constraint (32). First, assume that the central bank holds only one-period bonds on its asset side and has one-period reserves as well. Then, the central bank has no maturity mismatch and we have

$$Q_{1t}b^c_{1,t} - Q_{1t}l^c_{1,t} + T_t = b^c_{1,t-1}\Pi^{-1}_t - l^c_{1,t-1}\Pi^{-1}_t.$$  \hspace{1cm} (36)

Second, let’s consider the case that the central bank holds only two-period bonds on its asset side and has one-period reserves. Then, there is maturity mismatch on the central bank balance sheet, and we have

$$Q_{2t}b^c_{2,t} - Q_{1t}l^c_{2,t} + T_t = Q_{1t}b^c_{2,t-1}\Pi^{-1}_t - l^c_{1,t-1}\Pi^{-1}_t.$$  \hspace{1cm} (37)

Comparing (36) with (37) (which is easiest to see with a linear approximation) shows that the dynamics of the central bank balance sheet and transfers to the Treasury get affected by the short-term interest rate ($-Q_{1,t}$) in the first case, but by $Q_{1,t} - Q_{2,t}$, which using (29) is equal to $(-E_t Q_{1,t+1})$, in the second case. Both cases feature a short-term liability and so the short-term interest rate does not differentially affect (36) versus (37). The mechanism is then again driven by mean-reverting transition dynamics, such that $E_t Q_{1,t+1} = \rho Q_{1,t}$, with $\rho < 1$. Thus, with no maturity mismatch, there is no differential effect of changes in the short-rate on the net position, but with maturity mismatch, the short-rate affects the net position strongly, as it affects liabilities by ($-Q_{1,t}$) but assets by only $\rho Q_{1,t}$, where $\rho < 1$. When the central bank increases the extent of maturity mismatch on its balance sheet (which can be done either by keeping the size constant but making the maturity of assets longer, or increasing the size while keeping the maturity of assets the same), the current short-term interest rate ($-Q_{1,t}$) more directly affects the dynamics of the central bank net asset position and transfers to the Treasury. To smooth transfers to the Treasury, the central bank smooths the path of the short-term interest rate.

Now, consider a situation where the economy is exiting the ELB situation, or generally, a path where short-term interest rates are expected to rise in future and either taxes are expected to rise or transfers to the Treasury expected to fall. Then, as explained above, the central bank will have an incentive to keep the short-term policy rate low(er) on exit, if it engaged in quantitative easing while the economy was at the ELB. That is, the central bank will raise the short-term policy rate slowly and more smoothly. It is precisely this feature that affects private-sector

27 In other words, one can think of comparing the difference in return between asset and liability in the two cases as comparing ($-Q_{1,t} - (-Q_{1,t})$) with $(-E_t Q_{1,t+1} - (-Q_{1,t}))$. 

20
expectations at the ELB about the future path of conventional monetary policy and enables quantitative easing to have macroeconomic effects even without financial frictions or other restrictions on trade in financial assets.

2.2.4 Other models

We now briefly discuss some other important models of credit policy or central bank balance sheet policy.

Credit easing Curdia and Woodford (2016) use a borrower-saver model with credit spreads to analyze the efficacy of quantitative easing and credit easing policies. Households switch between being borrowers and savers, and competitive financial intermediaries channel funds from savers to borrowers. As financial intermediation uses real resources, a credit spread, a spread between the borrowing and saving rate, arises endogenously in equilibrium. Shocks cause the credit spread to vary exogenously. Curdia and Woodford (2016) analyze pure quantitative easing and credit easing. Quantitative easing is an expansion in central bank reserves, which is the same as the monetary base in the model. Credit easing is direct lending by the central bank to the private sector, at the private-sector borrowing rate. Here, the lending by the central bank is to the borrower type of household.

Pure quantitative easing is irrelevant in the model. That is, even an arbitrary expansion in central bank reserves, beyond a satiation level where the opportunity cost of holding reserves is zero (the opportunity cost is given by the difference between the saving rate and the interest on reserves), has no effect on macroeconomic prices and quantities. Clearly, this result holds at the ELB, where both the interest on reserves and the saving rate are zero. Credit policy, on the other hand, is not neutral in the model. When financial shocks increase the credit spread, central bank credit to the private sector can reduce spreads and mitigate the aggregate and distributional consequences. Moreover, such credit policy has similar effects regardless of whether the central bank finances lending to the private sector through expanding reserves or reducing the central banks holding of government debt.

Other credit frictions Williamson (2016) presents a model where financial intermediaries face a collateral constraint due to limited commitment/incentive problems. Moreover, short-term government debt is better collateral than long-term government debt and fiscal policy produces a chronic shortage of collateral. Thus, the total value of collateralizable wealth is below the level needed to support efficient exchange in the economy and incentive constraints on financial intermediaries bind. Fiscal policy keeps the real value of government debt constant over time by appropriately manipulating taxes. With these ingredients, the model generates an upward sloping yield curve, that is, an endogenous term premium. The term premium reflects the two key aspects of the model: a liquidity premium for short-term government bonds compared to long-term government bonds, as well as shortage of collateral in the economy.
To employ quantitative easing, the government swaps long-term government debt in the hands of the public for short-term government debt. This amounts to increasing the stock of good collateral in the economy, which flattens the yield curve by reducing the nominal yield on the long-term government debt. At the same time, real bond yields increase because the greater stock of short-term government debt, which is better collateral, loosens the incentive constraints of financial intermediaries. With rising real yields, inflation must decline to induce agents to hold a greater stock of real money balances in equilibrium. The model thus predicts that quantitative easing will increase real yields and decrease inflation.

**Incomplete asset market participation** Farmer and Zabczyk (2016), building on Farmer (2012c), present a two-period model where entrepreneurs, that is, agents who operate a production technology, do not trade in financial assets as such trades happen the period before they are born. That is asset market participation is incomplete due to an overlapping generations/finite life-time type set-up. Workers make consumption/savings and leisure decisions, receive transfers and are taxed. Entrepreneurs make consumption and production decisions and are taxed. The model features multiple perfect foresight equilibria because of the presence of money and the assumption that government transfers to workers are in nominal terms. Due to indeterminacy, Farmer and Zabczyk (2016) use a belief function to select an equilibrium.

The competitive equilibrium in the model is pareto inefficient. The model then considers unconventional policy in which the central bank issues indexed bonds and uses the proceeds to buy claims to the stock market (shares to profits), such that the returns are the same across these two assets. The key result in the paper is that such a policy can achieve the efficient allocation, the allocation that would prevail if there was complete asset market participation (where entrepreneurs would participate in trade of financial assets before they are born).

**2.3 Forward guidance**

Major central banks augmented asset purchases with forward guidance at the ELB to shape market expectations of expansionary conventional monetary policy. That is, by keeping short-term interest rates lower for longer than the usual reaction function would indicate. This is expected to raise output and inflation today. In the baseline model presented so far, while it is possible to discuss the theory of forward guidance, as the model does not feature nominal rigidities, nominal interest rate shocks not only have no effects on output, but also have an unconventional effect of inflation/prices.²⁸

To better illustrate the theory of forward guidance, we will slightly modify the firm's problem to incorporate sticky prices. Let the consumption good \( c_t \) be an aggregate of a continuum of

²⁸ That is, with flexible prices, a contractionary monetary policy shock today will lead to an increase in inflation.
differentiated varieties indexed by \( i \in [0,1] \),
\[
c_t = \left[ \int_0^1 c_t(i)^{\frac{1}{v-1}} \right]^{v-1},
\]
where \( v > 1 \) is the elasticity of substitution among the varieties. The household's expenditure minimization problem implies a downward-sloping demand function for the varieties. The dynamic optimization problem remains the same. A continuum of monopolistically competitive firms produce differentiated varieties and are indexed by \( i \in [0,1] \). Firm \( i \) produces output \( y_t \) with labor \( h_t \) as input
\[
y_t(i) = A_t F(h_t(i)),
\]
where the production function, \( F(h_t(i)) \), is increasing in \( h_t(i) \). Firms hire labor in a common, perfectly competitive factor market. Firm \( i \) sets price \( P_t(i) \) for its variety. We introduce nominal rigidities by having firms face a cost of adjusting prices, \( d \left( \frac{P_t(i)}{P_{t-1}(i)} \right) \), where \( d(.) \) is a convex function, and for simplicity, \( d(\Pi_t) = \frac{\kappa}{2} (\Pi_t - 1)^2 \). The demand function for variety \( i \) is derived from the cost minimization problem of the household and is given by
\[
\frac{y_t(i)}{y_t} = \left( \frac{P_t(i)}{P_t} \right)^{-v},
\]
where \( y_t \) is aggregate demand that is taken as given by the firms.

Firms maximize expected discounted profits over the infinite horizon
\[
E_0 \sum_{t=0}^\infty \Lambda_{0,t} \rho_t(i),
\]
where they use the stochastic discount factor \( \Lambda_{0,t} = \beta^t \frac{U_c(c_t,h_t)}{U_c(c_0,h_0)} \) to discount future profits and where flow profits are given by \( \rho_t(i) = A_t F(h_t(i)) - d \left( \frac{P_t(i)}{P_{t-1}(i)} \right) - w_t h_t(i) \). The problem of firm \( i \) is then to choose \( \{h_t(i), P_t(i)\}_{t=0}^\infty \) to maximize (40) subject to a sequence of production functions (38) and demand functions (39), while taking as exogenously given \( \{A_t, P_t, y_t, \Lambda_{0,t}, w_t\}_{t=0}^\infty \). As is standard, we focus on a symmetric equilibrium. After imposing equilibrium conditions and aggregation, this sticky price extension gives as the optimality condition
\[
\left[ \frac{(v-1)}{v} - \frac{U_h(c_t,h_t)/U_c(c_t,h_t)}{A_t F(h_t)} \right] y' + \kappa (\Pi_t - 1) \Pi_t = E_t \left[ \Lambda_{t,t+1} \kappa (\Pi_{t+1} - 1) \Pi_{t+1} \right].
\]
This equilibrium condition (41) replaces the equilibrium condition (15) under flexible prices in the simple model.\(^{29}\) The rest of the private sector equilibrium remains the same as before.

One can think of forward guidance in two ways, depending on how monetary policy is formulated. The first is to consider monetary policy as being determined optimally under

\(^{29}\) Flexible prices can be thought of as the limit when \( \kappa=0 \).
commitment, that is, Ramsey monetary policy. The central bank chooses a fully history-contingent path for its instrument \((Q_{1t}^{-1})\) to maximize household welfare \((2)\) subject to the private sector equilibrium and market clearing conditions, \((13), (16), \) and \((41)\).\(^{30}\) Eggertsson and Woodford (2003) and Jung, Teranishi, and Watanabe (2005), study such a policy while imposing the ELB on the short-term nominal interest rate. In their model, when the economy is at the ELB, optimal monetary policy under commitment entails a promise of lower policy rates in future, compared to a purely forward-looking policy. In particular, they show that optimal commitment policy keeps the short-term nominal rate at zero in future, even when it is possible to raise it. The forward-looking behavior of the private sector then affects the macroeconomy today, providing a boost to current inflation and output.

A second way to rationalize forward guidance is with reference to the feedback policy rule tradition. That is, policy is now conducted as in \((9)\), but with a “news” shock \(\varepsilon_{t-k}\)

\[
\beta Q_{1t}^{-1} = \left( \frac{\pi_t}{\Pi} \right)^{\psi_{1t}} \exp(\varepsilon_{t-k})
\]

\((42)\)

where \(k\) is the horizon of the news shock or forward guidance. This set-up models forward guidance as a negative anticipated shock to the monetary policy rule. That is, it can be used to assess how an expansionary, anticipated shock to the short-term interest rate (a negative \(\varepsilon_t\)), say \(k\) quarters ahead, affects macroeconomic outcomes today. The model is given by \((13), (16), (41), \) and \((42)\). In this case, a forward guidance shock raises inflation, and under a reasonable parameterization, also real output today, at positive interest rates. Thus, even if monetary policy currently is constrained by the ELB, a forward guidance shock modeled this way can have desirable effects on the macroeconomy today, through its positive effects on future output and inflation when interest rates are no longer constrained by the ELB.

2.4 Negative deposit rates

In addition to forward guidance, some central banks also implemented negative interest rates on central bank reserve balances. Traditionally, it has been thought that policy rates cannot fall (much) below zero, the so-called ELB. Such a result arises intuitively in standard macroeconomic models with fiat money or cash. The basic idea is that once interest rates fall to zero, then short-term government bonds and cash become perfect substitutes. If policy rates were to be below zero, then households can always hold cash, which would lead to an unbounded demand for money. This would not constitute an equilibrium.

\(^{30}\) We can assume that price adjustment costs get rebated back to the household in a lump-sum way so that the resource constraint does not change from before. Without this assumption, the non-linear resource constraint will reflect these costs.
More precisely, this intuition can be formalized by augmenting the utility function of households with real balances, for simplicity, in a separable way. The household maximizes

\[ E_0 \sum_{t=0}^{\infty} \beta^t [U(c_t, h_t) + V(m_t)], \]

where \( m_t = \frac{M_t}{P_t} \) is real balances with \( M_t \) nominal money and \( V(m_t) \) represents flow utility from real balances. Standard models assume that \( V(m_t) \) is strictly increasing (\( V'(m_t) > 0 \)), up to a satiation level \( m^* \). After that level \( m^* \), the marginal utility from holding real balances is zero (\( V'(m_t) = 0 \)). Given this maximization problem, a standard first-order condition that equates the marginal rate of substitution between consumption and real balances with the opportunity cost of holding money (that is, the short-term interest rate), then provides a money-demand function, where household demand for real balances depends negatively on the nominal interest rate. Such a micro-foundation implies that once interest rates are to zero and real balances are at the satiation level, \( m^* \), then interest rates cannot fall further in equilibrium. Theoretical monetary models therefore often directly impose a lower bound on nominal interest rates, simply alluding to this micro-foundation to justify such a constraint.

Some central banks have pushed their own deposit rates as much as 50 to 75 b.p. below zero. How can the standard text-book model described above be altered to account for this policy? To reconcile such an observation with the model, Rognlie (2016) proposes an extension, such that money demand remains finite at negative interest rates. The key idea in this extension is that \( V(m_t) \) is strictly increasing (\( V'(m_t) > 0 \)), up to \( m^* \) as before, but beyond \( m^* \), the marginal utility from holding real balances is not zero, but is instead negative (\( V'(m_t) < 0 \)). In this specification, \( V(m^*) \) represents the global maximum of \( V(\cdot) \), which is reached at zero interest rates. To sum up, in this generalized money-in-utility model, positive interest rates correspond to \( V'(m_t) > 0 \) while negative interest rates correspond to \( V'(m_t) < 0 \).

### 3. A Short History of Modern Unconventional Monetary Policy

This section describes the history of UMP by the four major central banks since 1999. Neely and Karson (forthcoming) provide a more detailed treatment.

---

31 These deposit rates have only partially been passed on by commercial banks. Retail rates have tended to remain non-negative.

32 Operation Twist in the early 1960s was an antecedent to modern UMP. This Federal Reserve program attempted to lower the long end of the yield curve in a previous. 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.
3.1 **The BOJ in 1999-2006**

Japanese equity and real estate prices soared to unsustainable levels in the late 1980s before plunging in the early 1990s, sending the Japanese economy into prolonged stagnation and deflation known as “the Lost Decade.” The BOJ responded to these conditions in 2001-2006 with unconventional policies that foreshadowed the post-crisis UMP of 2008-2018.

From 1991 to 2000, the BOJ repeatedly lowered its policy rate and tried to shape expectations by promising zero interest rates until “deflationary concerns are dispelled.” In February 1999, the BOJ reduced the uncollateralized overnight call rate to 0 percent, i.e., it implemented the zero interest rate policy (ZIRP). The BOJ followed this in April 1999 by promising to continue ZIRP until deflation was ended (Kuroda 2014).

Deciding that these measures were insufficient to bring about economic recovery and fearing further deflationary pressures, on March 19, 2001, the BOJ began to employ UMP by changing its main policy instrument from the overnight call rate to the quantity of reserves (termed “current accounts” by the BOJ) with the central bank (Figure 1) (see Bank of Japan 2001). The BOJ initially targeted a 25% increase in bank reserves to ¥5 trillion and promised to maintain this accommodative stance until inflation – which had been negative – firmly reached 0 percent. The BOJ repeatedly increased this reserves target, finally reaching a range of ¥30 – ¥35 trillion in January 2004 (Ito 2006). Figure 1 shows the assets and liabilities of the BOJ as a percentage of Japanese GDP. The BOJ purchased long-term Japanese government bonds (JGBs) and asset backed securities (ABS) to increase reserves and suppress long-term yields. After almost five years of UMP, on March 9, 2006, the BOJ cited upward movement in the CPI in deciding to revert to using the overnight interest rate as its main monetary policy tool. The BOJ meeting statement indicated a certain lack of confidence in UMP tools, as it stated that short term interest rates —which would remain zero — had the main effect on economic activity and prices (Bank of Japan (2006)).

3.2 **The Fed’s LOLR lending to asset purchases**

To support financial markets and alleviate the danger of systemic risk, the Fed created a number of lender-of-last-resort facilities during the financial crisis in 2007-2008 (Bullard, Neely, and Wheelock (2009), Neely and Karson (forthcoming)). These unsterilized lender-of-last-resort measures produced the first significant expansion of the Fed’s balance sheet in September 2008 but they are usually distinguished from UMP. Unsterilized measures are those that the central bank permits to affect the monetary base. When central banks reverse the effect of a transaction action on the monetary base, they are said to sterilize it.

---

Unsterilized measures are those that the central bank permits to affect the monetary base. When central banks reverse the effect of a transaction action on the monetary base, they are said to sterilize it.
The Fed followed these emergency lending programs with four large-scale asset purchase (LSAP) programs and augmented these measures with repeated forward guidance to shape expectations of accommodative future policy. The goal was to reduce long yields through both the expected short rate and term premium and ultimately to stimulate U.S. economic activity and maintain stable prices. The relative importance of bond markets in the U.S. economy doubtless led the FOMC to focus the Fed’s UMP on bond purchases and forward guidance, as opposed to banking support programs (Bini Smaghi, 2009). In 2016, outstanding U.S. debt securities were valued at 218 percent of U.S. GDP, while the euro area debt securities only reached 153 percent of euro area GDP.

To ease credit conditions, but especially those in housing markets, the Federal Open Market Committee (FOMC) announced the two components of the first round of Quantitative Easing (QE1) on November 25, 2008 and March 18, 2009, respectively, which eventually purchased a $1.725 trillion mix of federal agency debt, private mortgage-backed securities (MBS) and Treasuries. Housing-Government-Sponsored-Enterprise (GSE) debt and MBS accounted for more than 80 percent of these QE1 purchases, which roughly tripled the U.S. monetary base. FOMC statements during QE1 repeatedly returned to the theme of supporting housing through the mortgage market (see Board of Governors of the Federal Reserve System (2008)).

On November 3, 2010, the FOMC announced the second round of easing, QE2, that would purchase $600 billion in long-term Treasuries to “promote a stronger pace of economic recovery and to help ensure that inflation, over time, is at levels consistent with its mandate.” Figure 2 shows the evolution of Fed assets as agency/MBS and Treasury purchases replaced emergency lending on the Fed’s balance sheet. The Fed announced the Maturity Extension Program (MEP) — often termed “Operation Twist” — on September 21, 2011, which funded $400 billion of long-term Treasury purchases by selling short-term Treasury bills, rather than by monetary expansion. In response to slow nonfarm payrolls growth, on June 20, 2012 the FOMC extended the MEP, which had originally been scheduled to end in June, to December 2012. The FOMC’s intentions during these later programs was to more broadly ease financial conditions, reduce long-term interest rates, and the foreign exchange value of the dollar (see Board of Governors of the Federal Reserve System (2011)).

34 Bernanke (2002) presaged the Fed’s use of quantitative easing in addressing then-current deflation fears.
35 Both bonds issued or guaranteed by U.S. federal government agencies, such as the Government National Mortgage Association (Ginnie Mae), and bonds issued by U.S. government-sponsored enterprises (GSEs) are called “Agencies.” GSEs are corporations that Congress has created for a public purpose, such as to promote homeownership. GSEs include the Federal National Mortgage Association (Fannie Mae, the Federal Home Loan Mortgage (Freddie Mac) and The Federal Agricultural Mortgage Corporation (Farmer Mac). The U.S. Treasury backs bonds issued or guaranteed by federal agencies with the “full faith and credit of the U.S. government,” but bonds issued by GSEs may carry greater credit risk. (http://www.finra.org/investors/agency-securities)
36 The Fed was able to greatly increase the monetary base/bank reserves without losing control of the money supply because it could pay interest on reserves. The Financial Services Regulatory Relief Act of 2006 mandated that the Fed pay interest on reserves. While the policy was originally scheduled to start in 2011, that date was moved
Chairman Bernanke (2012) acknowledged that “the stagnation of the labor market in particular is a grave concern” and vowed that “the Federal Reserve will provide additional policy accommodation as needed.” In this environment, the FOMC announced QE3 on September 13, 2012, which would purchase $40 billion in MBS per month and it expanded QE3 on December 12, 2012, increasing monthly purchases to $85 billion by purchasing $45 billion in Treasuries each month. The expansion of QE3 replaced the MEP, which would end in January 2013. QE3 marked a turning point toward open-ended and contingent asset purchase programs, rather than a specified lump sum. The conditional nature of QE3 was consistent with Bullard’s (2010) argument that “quantitative policy should be respond to incoming information on the state of the economy.”

In the summer and autumn of 2013, rising employment and PCE inflation hovering near 1.5 percent allowed the FOMC to begin considering removing its unusual accommodation. Unfortunately, Chairman Bernanke’s efforts to signal this likelihood in May and June 2013 illustrated how unexpected central bank communication could roil financial markets by sharply boosting U.S. yields and the value of the dollar in an episode that became known as the “taper tantrum.”

Despite this market turbulence, the FOMC announced on December 18th, 2013 that it would start to gradually reduce its monthly QE3 purchases, contingent on the state of the economy. After a number of modest reductions, the FOMC officially ended QE3 on October 29th, 2014, but continued reinvesting principal and coupon payments to maintain its $4.5 trillion balance sheet. QE3 purchases totaled roughly $1.6 trillion.

3.3 The BOE’s Asset Purchase Facility (APF)

The BOE faced similar economic conditions to the Fed and pursued similar asset purchase policies to reduce long yields and provide broad monetary stimulus. Specifically, on January 19, 2009, the BOE announced an asset purchase facility (APF) that would buy £50 billion in commercial paper and corporate bonds. Although the BOE’s APF initially sterilized its long-term bond purchases by selling short-term gilts — as the U.S. MEP initially did — within months, the APF began financing its asset purchases with reserve creation, which nearly quadrupled the U.K. monetary base by the end of 2009. In its initial statements regarding the APF, the BOE emphasized market functioning — liquidity and trading activity (see Bank of England 2009, and Benford, Berry, Nikolov, Robson, and Young (2009)) — but later shifted to nominal income and the inflation target (see Bank of England 2012a). The BOE repeatedly forward to October 2008. The ability to pay interest on reserves also allowed the Fed to eventually raise the funds target in 2015-2018, despite the existence of plentiful banking reserves, which would otherwise have kept short term interest rates near zero. The Fed supplements interest on reserves with reverse repo transactions with institutions not eligible for reserve accounts. (https://www.frbsf.org/education/publications/doctor-econ/2013/march/federal-reserve-interest-balances-reserves/)
increased APF purchases of medium and long-term gilts over 2009-2016, eventually reaching authorized holdings of almost £450 billion. Figure 3 illustrates the increase in BOE assets.

### 3.4 The ECB responds to the debt crisis with SMP/OMT

While the Fed and BOE intended their bond purchase programs to broadly depress bond yields and provide general stimulus, the ECB deployed its first major asset purchase program for narrower purposes, to support troubled sovereign debt markets. Indeed, Figure 4 illustrates that after a jump in ECB assets in September 2008, to provide emergency liquidity during the financial crisis, ECB assets as a percentage of GDP did not grow much for the next three years.

The financial crisis entailed fiscal stimulus and/or bank recapitalization programs that significantly worsened fiscal balances for many European nations. Such deficit spending threatened to make preexisting debt problems unsustainable. Downgrades in sovereign debt ratings over 2009-2010 ratified the erosion of confidence in these nations’ debts and boosted many sovereign yields.

With yields on Greek, Portuguese and Irish sovereign debt climbing, the ECB introduced the Securities Markets Program (SMP) in May 2010 to purchase government debt, promote depth and liquidity and reduce yields in troubled euro area sovereign debt markets (see European Central Bank 2010). With purchases conducted on an as-needed basis and sterilized, the SMP would eventually accumulate as much as €220 billion in euro area sovereign debt with all purchases in 2010-2012.

The SMP program lacked an enforcement mechanism to ensure that countries whose debt was purchased took steps to regain fiscal stability. In September 2012, the ECB remedied this deficiency by replacing the SMP with the Outright Monetary Transactions (OMT) program. To make sovereign bonds eligible for purchase under the OMT, nations would be required to submit plans for fiscal consolidation and financial reform, subject to the European Stability Mechanism (ESM). Although the ECB has not purchased any bonds through the OMT, policymakers credit the OMT announcement with quelling fears of fiscal default and the dissolution of the euro area (Cœuré 2013).

### 3.5 Banking support programs

During and immediately after the financial crisis, the Fed and BOE focused on asset purchase programs while the ECB initially conducted a comparatively modest UMP program to support financial intermediation and sovereign bond markets. The ECB was more skeptical of risks to real activity than were the Fed and BOE and had greater concern about upside risks to inflation, which spiking oil prices temporarily had driven to 4 percent in the summer of 2008.

Cognizant of risks to the banking system, however, on October 15, 2008, the ECB announced a “fixed-rate full allotment” (FRFA) policy to elastically supply fixed-rate, collateralized loans...
banks. The ECB also supported bank funding through a covered bond purchase program (CBPP), announced on May 7, 2009, through which it would acquire €60 billion in bonds. It followed this program with an additional €40 billion in purchases in 2011 (CBPP2). These programs allowed banks to securitize loans and diversity their funding, thereby maintain credit for households and firms at accessible rates (see European Central Bank 2012, Trichet 2009a, and Trichet 2009b).

The BOJ also took an early but initially very modest step to support bank lending, in the form of the Growth-Supporting Funding Facility (GSFF), announced on May 21, 2010. The GSFF offered financial institutions low-cost loans of up to ¥1 trillion to support new businesses, technological research, hospitals, universities and housing, thereby supporting growth and overcoming deflation (see Bank of Japan Monetary Affairs Department 2010).

The BOE faced the challenge of providing collateral to a banking system that was awash in reserves after the initial asset purchases. On July 13, 2012, the U.K. Treasury and BOE jointly announced the first “conditional credit program,” the Funding for Lending Scheme (FLS), that would lend banks U.K. Treasury bills to use as collateral in money markets, in exchange for lower quality assets, in order to boost lending to U.K. households and non-financial companies (see Bank of England 2012b). The FLS employed lending incentives: Banks with declining (rising) lending to the nonfinancial sector would pay a higher (lower) interest rate on borrowed FLS assets.

The FLS started small, disbursing only £20 billion in U.K. Treasury Bills in its first year but it grew to a moderate size, peaking in 2015:Q4 at £70 billion ($100 billion), equal to 5.5 percent of the U.K. banking sector’s outstanding loans to the nonfinancial sector. The BOE soon evaluated the FLS to be a success and therefore extended and expanded the FLS several times before officially ending new drawdowns on January 31, 2018 (Churm et al. 2012).

The FLS was the second of six conditional credit programs by the major central banks that established incentives for bank lending to households and businesses. These programs conditioned either borrowing quantities or interest rates on each bank’s loan growth and they often also offered loans for 3-4 year terms, unusually long maturities for borrowing from central banks. The use of long maturities reduces rollover risk and transformation risk.

In October 2012, the BOJ announced a second conditional bank lending facility, the Stimulating Bank Lending Facility (SBLF), which began allocating funds in June 2013. Like the BOE’s FLS, the SBLF was intended to provide incentives for bank lending in order to support growth (see Bank of Japan 2014). The SBLF also conditioned the price of credit on a bank’s loan growth, although the SBLF lent money, not bonds, and did not penalize banks for scaling back loans. The SBLF pledged to fund up to 100 percent of banks’ increases in net lending relative to

37 The six programs would consist of the following: FLS, TFS, TLTRO-I, TLTRO-II, GSFF and SBLF.
2012:Q4 though loans with maturities of 1-3 years, although loans could be rolled over for a fourth year. In February 2014, the BOJ extended the SBLF and expanded its funding capacity.

The SBLF became the largest conditional lending program among those administered by the four major central banks relative to the domestic banking market or nominal GDP. Together, the GSFF and SBLF provided about 10 percent of outstanding bank loans to Japanese nonfinancial firms by July 2018, but the GSFF and SBLF loan disbursements are scheduled to end in June 2019 (see Bank of Japan 2018). The BOJ’s heavy reliance on GSFF and SBLF lending reflects the crucial role of bank lending in Japan.

3.6 The BOJ gets serious in 2013-2018

Figure 5 shows that BOJ assets grew very little in 2008-2012, illustrating that its lender-or-last resort and banking support actions were largely sterilized in this period, unlike those of the other three major central banks. During this time, Japan continued to experience unwelcome deflation and very slow growth. Therefore, while the Fed considered whether and how to remove some of its unusual monetary accommodation in 2013, the BOJ moved earnestly to stimulate the economy.

Following the landslide electoral victory of Prime Minister Shinzo Abe on December 26, 2012, the BOJ moved strongly to counter persistently sluggish economic activity. The stimulative measures included large and open-ended asset purchases, a doubling of the inflation target from 1 to 2 percent, and the GSFF and SBLF, the latter two programs were collectively dubbed the Loan Support Program (LSP). To counter further unwelcome moves toward deflation, the BOJ again officially changed its main policy instrument to “QQ targeting” on April 4th, 2013. The new policy, “Quantitative and Qualitative Easing” (QQE), used open-ended, contingent asset purchase programs to increase the size and maturity of the BOJ’s asset holdings. The QQE strategy committed the BOJ to purchase ¥50-55 trillion ($500 billion) in assets per year, mostly longer-dated Japanese Government Bonds (JGBs), but also small amounts of ETFs, J-REITs, commercial paper and corporate bonds. The QQE announcement exceeded market expectations by promising to boost the BOJ balance sheet by about 0.9 percent of GDP per month, which was relatively larger than the Fed’s QE3, which enlarged the Fed’s balance sheet by only 0.5 percent of U.S. GDP each month. The BOJ intended the size of the program to drastically change market expectations, increasing economic activity and inflation expectations (see Bank of Japan 2013). The BOJ hoped to achieve two percent inflation within two years. Over 2014-2015, renewed deflationary pressures prompted the Monetary Policy Board of the BOJ to twice extend the GSFF and the SBLF for a year at a time, increase their lending capacity, increase the maturity limit of GSFF loans from three to four years, expand the pace of QQE monthly asset purchases by 63 percent and extend the average maturity of its JGB portfolio to a 7-10 year target range.
3.7 The ECB responds to deflation fears

In the spring and summer of 2013, the ECB, like the BOJ, confronted forecasts of sluggish growth and fears of deflation (Kang, Ligthart, and Mody 2015). Figure 6 shows that the ECB Governing Council lowered policy rates in May and November 2013, reducing the main refinancing operations (MRO) rate to just 0.25%. In July, the Council provided expansionary forward guidance by stating that key ECB interest rates would remain at or below then-current levels for an extended period (Draghi and Constâncio 2013). Despite these measures, the monetary base — and particularly Longer-term Refinancing Operations (LTROs) — shrunk in 2013-2014. Figure 4 illustrates this steady reduction in ECB assets as-a-percentage-of-GDP from late 2012 to late 2014.

With euro area inflation at only 0.5 percent, on June 5th, 2014, ECB President Mario Draghi announced a series of stimulatory measures: negative deposit rates, a conditional bank lending program known as Targeted Longer-term Refinancing Operations (TLTROs) and hints of further asset purchases. The ECB became the first of the four major central banks to set a negative deposit rate (-0.1 percent) on excess reserves (Figure 7), which the Governing Council couched in terms of ensuring price stability. The TLTRO resembled the BOE’s FLS and the BOJ’s SBLF in providing incentives for bank lending to households and non-financial corporations (Draghi 2014a). Specifically, the TLTROs conditioned banks’ borrowing allowances on net increases in loans to the nonfinancial sector. The TLTRO also included long-term (4-year) loans to banks at low interest rates, that is, 10 b.p. above the MRO rate.

The TLTRO had disbursed loans worth €425 billion by its final major allotment on March 24, 2016, at which point it was the largest of the three existing major conditional credit programs — TLTRO, SBLF and FLS — in absolute terms, but the SBLF remained the largest relative to its outstanding bank loans to the nonfinancial sector. The TLTRO and SBLF were 4.4 and 6.4 percent of outstanding bank loans in the euro area and Japan, respectively. By 2014:Q4, the conditional credit programs of the BOE, BOJ and ECB combined for a total of almost $400 billion of outstanding loans to banks.

Euro area inflation continued trending toward undesirably low levels while bank lending to euro area businesses reached a seven-year low. To keep inflation near to but below 2 percent, on September 4th, 2014, the ECB Governing Council lowered its MRO rate to nearly zero (0.05 percent), its deposit rate further into negative territory (−0.2 percent, Figure 7), and announced an Asset-Backed Securities Purchase Program (ABSPP) and a new Covered Bond Purchase Program (CBPP3) (Draghi 2014b, and Draghi 2014c). The ECB initially did not specify a purchase amount or pace but on November 6, 2014, Draghi clarified that the asset purchase

programs and TLTROs would increase the ECB’s balance sheet by roughly €750 billion ($950 billion) by June 2016, restoring the monetary base to its early-2012 size. President Draghi described CBPP3 and ABSPP as credit easing, not QE, because they supported covered bond and ABS markets, although they also expanded the monetary base (Figure 4).

On January 22, 2015, the ECB responded to further deflation fears by creating a Public Sector Purchase Program (PSPP) to buy medium- and long-term bonds issued by euro area governments, agencies and European institutions. The ECB’s monthly purchases of €60 billion under the APP – the PSPP, the CBPP3 and ABSPP – would continue until the euro area experienced a “sustained adjustment” in inflation and real activity or through September 2016. The asset purchase programs expanded the ECB’s balance sheet by over €650 billion (30 percent) over 2015, increasing the ECB monetary base from 22 to almost 28 percent of euro area GDP by the end of 2015 (Figure 4). This aggressive, state-contingent asset purchase program mirrored the BOJ’s ongoing QQE and the Fed’s QE3, which had concluded in October 2014.

Despite the asset purchases in 2015 and a modest drop in borrowing costs, euro area inflation remained undesirably low and loans to businesses fell throughout 2015. To counteract these conditions, in December 2015 the ECB extended the APP until at least March 2017 and added regional and local euro area governments debt to the PSPP. The ECB also began reinvesting principal payments from maturing APP securities to maintain its asset holdings.

In response to preliminary estimates of further drops in euro area inflation, on March 10, 2016, the ECB Governing Council announced that it would 1) cut its deposit rate further into negative territory (Figure 7), 2) implement a new bank lending program, i.e., TLTRO II and 3) expand its APP by establishing the Corporate Sector Purchase Programme (CSPP).

TLTRO-II rewarded increased bank lending with reduced interest rates on borrowed funds. Borrowing rates started at the MRO rate (0 percent) and could be reduced to the deposit rate (-0.4 percent) for banks that expanded lending by 2.5 percent or more. The TLTRO-II’s price incentives contrast with the quantity incentives of the BOJ’s SBLF and the first TLTRO program.

The ECB designed the Corporate Sector Purchase Programme (CSPP) to lower funding costs for euro area businesses. The program temporarily increased the ECB’s bond purchase rate by 33 percent to €80 billion per month before the ECB returned it to the previous pace in March 2017. From June 2016 until March 2017, the ECB corporate bond purchases averaged €7.5 billion per month and allowed the CSPP to acquire over 11 percent of the “CSPP-eligible bond universe” as of June 7, 2017 (European Central Bank 2017).

The March 10, 2016 ECB announcements of deeper negative rates, the TLTRO-II and expanded asset purchases again illustrated the difficulty of communicating without roiling financial markets. President Draghi accompanied these expansionary announcements with the
caveat that the ECB would likely not further ease policy, a combination that whipsawed asset prices about as much as the better-known Fed “taper tantrum” of June 2013.

3.8 The BOJ and BOE react to Brexit

The citizens of the United Kingdom voted to leave the European Union on Thursday June 23, 2016. This “Brexit” vote substantially increased uncertainty and financial volatility and produced a flight to safe assets that appreciated the JPY while depreciating the GBP. In response to these trends, the BOJ announced on July 29, 2016, that it would double its ETF purchases and its USD lending operations to ensure firms’ access to foreign currencies and bolster business confidence (Figure 5) (see Bank of Japan 2016a).

In response to the GBP depreciation and a very large fall in business activity, on August 4, 2016, the BOE cut its policy rate from 0.5 percent to 0.25 percent, expanded its APP and introduced a conditional, collateralized bank-lending program, the Term Funding Scheme (TFS) (Figure 6). The BOE raised its authorized APP holdings from £375 billion to £445 billion, including additions of £10 billion in U.K. corporate bonds and £60 billion in U.K. government bonds. The TFS’ interest rate incentive structure was similar to that of the FLS, imposing higher borrowing costs on banks with declining loan volumes. The TFS lent money, however, rather than government securities. The TFS would eventually lend U.K. banks over £100 billion ($130 billion), about 5 percent of banks’ loans to households and firms, by January 2017, exceeding the FLS at its peak value. These post-Brexit asset purchases and TFS loans enlarged the BOE’s balance sheet by 47.5 percent, from £400 billion in June 2016 to £590 billion in August 2018. Figure 3 shows this growth of BOE assets as a percentage of GDP from late 2016 through 2017. The BOE motivated these measures as designed to provide funding to the real economy, to insure against risks to banks’ funding, to meet the 2 percent inflation target and lay the groundwork for growth and employment (see Bank of England 2016).

3.9 The BOJ yield curve targeting

Despite introduction of negative deposit rates in January 2016 and the modest post-Brexit stimulus, Japanese inflation continued to be undesirably low. At the same time, yield curve inversion was threatening the profitability of Japanese financial institutions. In response, on September 21, 2016, the BOJ announced a new policy, “QQE with Yield Curve Control,” targeting both the overnight deposit rate and the 10-year JGB yield at -0.1 percent and 0.0 percent, respectively (Figure 7) to achieve the price stability target of 2 percent (see Bank of Japan 2016b). The BOJ thus became the first and only central bank to explicitly target longer-dated yields. Governor Kuroda also committed the BOJ to “inflation-overshooting,” that is, to maintain a pace of asset purchases until year-over-year inflation “exceeds the price stability target of 2 percent and stays above the target in a stable manner.”
3.10 Fed, ECB and BOE normalization

As the U.S. economy improved in 2014 and 2015, the FOMC began to consider whether and how to reduce the unusual monetary accommodation, return to using the federal funds rate as a policy tool and gradually reduce the Fed’s balance sheet. On December 16, 2015, with U.S. unemployment having declined to 5 percent, the FOMC raised the federal funds target range by ¼ percentage point to a range of 25 to 50 basis points. By May 2018, the FOMC would raise the target range five more times to bring the upper limit of the federal funds target range to 1.75 percent.

On June 14, 2017, the Fed announced a plan to reduce its $4.5 trillion in assets by retiring coupon and principal payments as it received them. The Fed would allow a maximum of $6 billion in Treasuries, $4 billion in agency debt and MBS to be retired each month, starting in October 2017. The Fed would raise those maxima by $6 billion and $4 billion, respectively, each quarter during the first year of the normalization strategy.

Chair Yellen specified no final goal for the Fed’s balance sheet, stating only that the asset holdings would be “appreciably below that seen in recent years but larger than before the financial crisis” (Board of Governors of the Federal Reserve System (2017)). The normalization announcement did not significantly move asset prices, probably because the announcement had been long-expected and was accompanied by a detailed schedule (Appelbaum 2017 and Timiraos 2017).

Even as the Fed announced these normalization plans, improving euro area economic conditions led the BOE and ECB to similarly consider returning to more neutral policies.

The post-Brexit performance of the U.K. economy was reassuringly good, prompting the MPC, in September 2017, to warn of the likelihood of withdrawal of unusual stimulus. With inflation reaching 3 percent and unemployment at 4.2 percent, the MPC raised its policy rate for the first time in a decade, to 0.5 percent in November 2017 (Figure 6). The MPC continued to provide warning in February 2018 that monetary policy may need to be “tightened somewhat earlier and by a somewhat greater extent.”

Core euro area inflation had risen to 1 percent in April 2017 for the first time in more than a year, while real GDP growth surpassed 2 percent in the first half of 2017. On October 26, 2017, the ECB announced that, if the euro area economy continued to perform well, it would reduce monthly APP bond purchases by half, to €30 billion, as of January 2018, and end new asset purchases entirely in September 2018. The ECB did reduce monthly APP bond purchases by half in January 2018. Figure 4 illustrates the leveling off of ECB asset growth in 2018. The ECB governing council continued to move toward normalization in June 2018 when it clarified that it would reduce monthly asset purchases to €15 billion from October through December 2018, at which point it would end net purchases, so long as the medium-term inflation outlook remained favorable. But the ECB also planned to reinvest principal payments from maturing securities for...
“an extended period.” The ECB Governing Council described all moves as being contingent on a path for inflation close to but below 2 percent.

3.11 Central bank evaluations of the UMP

Central banks have carefully watched the results of both their own and foreign UMP programs in order to evaluate their impact on the economy and plan future programs. One must be careful about generalizing central bank evaluations of UMP because, as previously noted, UMP programs were heterogeneous, ranging from banking support programs — both direct lending and narrow asset purchase to provide funding — to negative interest rates and broad asset purchases for general stimulus. Programs also differed in operational details and in the circumstances in which they were employed.

Even with this caveat about the dangers of generalization, it is fair to say that, on the whole, central banks were quite positive, but measured, about the impact of their UMP. While one might not expect central banks to admit failure, it is telling that major central banks used the same types of programs repeatedly, which suggests that they were happy with the results. Central banks also tended to borrow ideas — e.g., asset purchases, incentives for lending, negative interest rates — from each other, which again suggests that central banks considered other authorities’ programs to be successful.

Some of the earliest and least unconventional programs were those to elastically supply liquidity to markets during the financial crisis. Central bankers were pleased with these liquidity support programs, such as the ECB’s FRFA. On June 6, 2011, Trichet summarized, “[T]he decisions we took during the crisis were effective. They have ...helped to preserve a very solid anchoring of inflation expectations” (Trichet 2011 and also Trichet 2009c).

Central banks also praised the conditional bank lending programs. On May 14, 2015, Mario Draghi lauded the TLRTO, “Lower rates have ... created more net demand for borrowing. And banks have then begun to search for the ‘next tier’ of borrowers, leading to a gradual easing of credit standards... ... [I]t has led to a convergence in the cost of borrowing across euro area countries” (Draghi (2015a)). Mark Carney likewise expressed the BOE’s satisfaction with the TFS, “The TFS has been effective at ensuring that the low level of Bank Rate has been passed through to real economy lending rates” (Carney 2017).

The most important and closely watched programs were the broad asset purchase programs. There was again broad but measured appreciation for these programs. In the aftermath of Fed asset purchases, for example, Fed officials — Bernanke (2010), Bernanke (2012), Powell (2013), and Fischer (2014) — stated that such transactions reduced Treasury, corporate and MBS long yields, boosted stock prices and significantly aided the recovery. In an August 2014 speech, Fed Vice Chair Stanley Fischer gave measured approval, “I consider quantitative easing to have been largely successful” (Fischer 2014). Similarly, by late 2011, the BOE considered the APF to have successfully lowered yields and affected the economy similarly to a sizable cut in short rates.
Likewise, Mario Draghi endorsed the ECB’s UMP, “The ECB’s monetary policy measures have clearly worked ... they are probably the dominant force spurring the recovery. They have been instrumental in arresting and reversing the deflationary pressures” (Draghi 2015b). The BOJ observes on its website that “a combination of the negative interest rate on current account balances at the Bank and purchases of Japanese government bonds (JGBs) is effective for yield curve control.”

Central bankers readily acknowledge that, although useful, asset purchases are not a magic wand. Their positive effects must contend against other forces, such as the depths of the financial crisis and/or stubborn expectations. Comments by Deputy Governor Ben Broadbent of the BOE and then-Governor Powell of the Federal Reserve highlighted recognition of the limitations of such policies. Deputy Governor Broadbent gave a measured assessment, “As far as we can tell, asset purchases provided significant support to aggregate demand, even if it wasn’t enough to offset fully the extended contractionary effects of the crisis” (Broadbent 2018). Governor Powell provided a similarly calculated view, “My view is that the LSAPs continue to provide meaningful support for economic activity but perhaps less than what the FRB/US estimates suggest” (Powell 2013).

Perhaps the most notable failure for UMP has been in (failing to raise) Japanese inflation, which remained persistently low since the mid-1990s. Hiroshi Nakaso, Deputy Governor of the BOJ, acknowledged both the BOJ’s successes and remaining problems in employing UMP, “QQE has brought about a steady improvement in Japan’s economy, but the price stability target of 2 percent is yet to be achieved. The main reason for this is that inflation expectations remain weak” (Nakaso 2017).

In summary, central banks viewed their UMP as broadly helpful tools but limited in the same way that all economic tools are limited.

4. **Unconventional Policy Effects on Financial Markets**

4.1 **Event study methodology**

UMP are heterogeneous and there many ways to evaluate their effect on financial markets. Because asset purchases are perhaps the most important and most commonly studied UMP and those purchases are usually studied with variations on event studies, this subsection discusses event study methodology in the context of unconventional asset purchases.

---

An efficient, forward-looking financial market should immediately incorporate available information into prices. In the context of unconventional asset purchases, the forward-looking nature of financial markets means that researchers must examine the effects of policy announcements — or other news — on financial markets rather than waiting 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 heterogeneity in interpretations. Markets typically react to simple, scheduled announcements, such as regular macro news releases, in seconds or perhaps a few minutes. Unconventional asset purchase announcements are much more complex and sometimes produced reactions that appeared to last for hours or even days. Moreover, the efficient markets hypothesis implies that the short-term impact of some announcement is also expected to be approximately its long-term impact to preclude an implausible profit opportunity in financial markets.

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 most often evaluated the effects of unconventional policy on asset prices with “event studies.” Event studies examine asset prices in a window around some surprising incident to determine the effect of that incident on the asset prices. Such studies generally must assume that one can identify and measure the relevant shocks, that the immediate reaction to the announcement is also approximately the long-run effect, and that other news has negligible effects during the event window.

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 an announcement’s surprise component. That is, they estimate regressions of the form

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

(44)

where \( r_t \) is the asset’s return (or perhaps its volatility) and \( \text{surprise}_t \) measures the surprise component of the announcement. For instance, to study conventional monetary shock effects 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, event studies of macro announcements (e.g., unemployment) would measure the surprise as the announced macro release less an expectation derived from surveys of market participants. Including the whole announcement number (expected component + surprise) in the regression, rather than just the surprise, will bias the estimated coefficient toward zero.

In a study of unconventional monetary policy, one would ideally like to know how much a given announcement changed the market’s expectation of future purchases, i.e., the quantity surprise. That would allow one to estimate the effect of a given purchase on yields. Unfortunately, econometricians mostly lack reliable estimates of how much a given
announcement changed the market’s expectation of the path of the UMP instruments, that is, of the quantity of asset purchases. Thus, researchers cannot usually directly measure asset purchase quantity surprises.

One can, however, measure a monetary surprise with the 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.

\[ r_t = a + b \Delta \text{yields}_t + e_t \]  

(45)

Such a regression, however, can only describe the reaction of other asset prices to a given change in long yields, that is, the covariance of asset returns after an unconventional shock. 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.

\[ r_t = a + b_1 I_t(\text{easing announcement}_t) + b_2 I_t(\text{tightening announcement}_t) + e_t \]  

(46)

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 all the changes in expectations about a program occurred during some finite set of events, then the sum of the asset price changes after those events would estimate the total impact of the program. 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.

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 Correia-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. Wu (2014) and Ihrig et al (2018) have put together forward looking expectations of debt/purchases. In addition to the SPD, several authors have proposed measuring the effects of surprising changes in the distribution of asset purchases across the yield curve. This can be used to measure “local supply effects,” as will be discussed.

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.
Consider an example: A central bank institutes a bond buying program in an economy 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: In a completely surprising announcement, 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 terms of yield changes.

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, which inevitably implies a bias/efficiency trade off. Smaller event sets may miss important changes in policy expectations and thus be biased. In contrast, large event sets may contain irrelevant 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.

Because the initial asset purchase programs of the Fed and the BOE were relatively novel programs in 2008-2009 and markets were unfamiliar with central banks’ reaction functions for unconventional policy, it is plausible that central bank communications produced all important changes in expectations about the initial asset purchase programs. Researchers have exploited this assumption to estimate the impact of these initial programs on asset prices (Gagnon et al. 2011; Joyce, Tong, and Woods 2011). For later rounds of unconventional asset purchases, however, markets were aware asset purchases were possible and more familiar with the central bank’s reaction function. Therefore, market expectations probably changed frequently in response to all sorts of news and thus it is less plausible that one could estimate the total impact of later QE programs.

To avoid the fairly strong assumptions of event studies, researchers have also explored the impact of UMP with other methods. In particular, researchers have sought to use regression

42 The BOJ had purchased assets in 2001-2006 to expand its balance sheet, but these were smaller in scale and under different circumstances. That experience seemed to provide limited information to markets.
methods with lower frequency (i.e., monthly or quarterly) data to examine the robustness of event study conclusions.

4.2 Methods to assess channels of monetary policy

In addition to studying the effects of UMP asset purchases on long yields, one would like to know how such transactions influence yields to inform policy design and welfare analysis. To study the channels of bond purchases, one can decompose long yields 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 risks: duration risk, local scarcity, default risk, prepayment risk, liquidity, and safety.

By estimating how an asset purchase announcement changes expected futures short rates versus term premia, researchers can distinguish between “signaling” and “portfolio balance” effects. Signaling directly affects the expected average overnight yield while portfolio balance (and other related) effects impact the term premium. Changes in the expected future short rate are termed “signaling” effects because central banks are assumed to control future short rates and therefore changes in those rates are said to come from “signals” sent by central banks. Two tools, term structure models (TSMs) and swap rates, decompose yield changes into changes in the expected average overnight rate and changes in term premia.

TSMs are time series models of the stochastic discount factor (SDF) that preclude arbitrage and imply expected time paths for bond prices and yields at each point in time. A TSM’s forecast of the term premium is the long yield less the average expected future short rate. An estimated TSM implies how an announcement affects the predicted paths of these variables.43

Swap rates constitute an alternative way to measure expected future interest rates and term premia. A swap rate is the fixed interest rate that the marginal market participant is willing to exchange for floating rate payments. Under risk neutrality, the swap rate would be the expected average short-term interest rate over the interest rate swap’s horizon. Market participants are not risk neutral, the swap rate surely contains a risk premium. But if the risk premium is relatively small and slowly changing compared to the average short-term interest rate, then changes in the swap rate at the time of an UMP announcement can be interpreted as reflecting changes in the average short-term interest rate, which is interpreted as a signaling effect. The plausibility of this assumption is subject to dispute.

43 Such calculations implicitly assume that the policy announcement does not change the parameters or structure of the TSM.
For asset purchases to produce portfolio balance effects, investors must view other assets as imperfect substitutes for the purchased assets. At least three distinct types of risks can produce portfolio rebalancing: duration risk, local scarcity and safety.

Removal of duration from the market can produce a classical portfolio balance effect as agents require less compensation to hold the remaining duration risk. Bond purchases that remove duration risk should produce monotonically greater effects on bonds with longer duration. That is, 20-year bond yields should decline by more than 10-year bond yields.

The second type of effect that is sometimes termed a portfolio balance effect is the “local supply” or “local scarcity” effect. This type of effect generally requires some market segmentation, i.e., some agents strongly prefer to hold bonds of certain maturities, perhaps to closely match the maturities of their liabilities. These agents will accept a lower yield to hold assets of these specific maturities and arbitrage is insufficient to eliminate the risk premium. Local supply effects differ from duration removal in that bond purchases should affect the prices of the closest substitutes (i.e., fixed income securities with the closest maturity), rather than affecting securities according to their sensitivity to duration.

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 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 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 reflect the value of the borrower’s call option. 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.

By comparing the reactions of asset prices that have different exposure to risk around policy announcements, one can assess how the policy announcements affect the compensation for that type of risk. For example, the difference between long-term Treasury and long-term corporate yields reflects perceived default and liquidity risk. 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 is an example of a “difference-in-difference” strategy.

Changes in interest rates through any channel will generally change other asset prices, such as exchange rates, stock and real estate prices. Such asset prices, in turn, will influence consumption and investment. Purchases of assets will also generally increase bank reserves, which may stimulate bank lending through the banking channel.

4.3 The Pre-crisis literature on UMP

Prior to substantial experience with UMP, persistently very low inflation and sluggish real activity in Japan in the 1990s led many researchers to consider how to stimulate an economy when the usual nominal interest rate tools had limited effectiveness because of low inflation and a zero bound on nominal interest rates. Collectively, these researchers discussed nearly every method of UMP to be tried later, as well as some that were never put into action.

Lebow (1993) makes the case that open market purchases would still be slightly expansionary, even at the ELB, partly because they would flatten the yield curve by signaling near-term rate increases were unlikely. The paper further discussed direct lending to the non-bank public or purchases of gold or private securities. Clouse et al. (2000) focus specifically on the Fed’s legally available tools (defined by Federal Reserve Act) for a low-inflation environment: quantitative easing, foreign exchange intervention, discount window lending and even writing options on short-term interest rates. All of these tools might be used to signal intentions about future monetary policy. The authors conclude that the Fed has a number of potentially useful, legal tools at its disposal but economic circumstances would dictate the choice. Goodfriend (2000) explores several options for defeating the zero lower bound, including negative deposit rates (a carry tax on reserves), purchases of long bonds and money transfers, which could be effected through monetary financing of debt. McCallum (2000) explores theoretical issues around an ELB for nominal interest rates, suggesting that monetary stimulus could still be pursued through the foreign exchange market.

The previously discussed papers sought ways to escape a situation in which nominal interest rates are trapped at or near the ELB. Reifschneider and Williams (2000) tackle construction of a monetary rule to avoid this problem in the first place. Using the FRB/US model to quantify interactions, these authors argue that if the central bank can credibly commit to future policy, then a promise to keep short rates low after the non-negativity constraint no longer binds allows monetary policy be effective at the ELB. That is, this paper foreshadowed the later debate on

---

44 FRB/US is a large-scale model the U.S. economy that Federal Reserve Board economists use for forecasting and policy analysis.
signaling and promising to keep short rates lower for longer than a perfect-commitment
conventional reaction function would imply, sometimes called “promising to be irresponsible.”

4.4 The BOJ’s forward guidance and quantitative easing: 1999-2006

In 1999-2006, the BOJ employed both forward guidance and asset purchases to attempt to
achieve price stability and stimulate the economy. These first modern UMP programs taught
valuable lessons to both central bankers and economists who tried to evaluate them. To provide a
reference and shorten the text, a table in Appendix A details the methods and data from the
empirical studies of UMP discussed in the rest of Section 4.

Okina and Shiratsuka (2004) made an early methodological contribution in introducing TSM
event studies to the literature on UMP. With an estimation sample of March 1998 through
February 2003, Okina and Shiratsuka (2004) examine 17 events from September 9, 1999 through
October 30, 2002, finding that BOJ policy in the later part of their sample relied heavily on a
signaling effect, which they termed a “policy duration” effect.

Perhaps because the BOJ emphasized the quantity of bank reserves (denoted as “current
account balances” (CAB) by the BOJ) as its target, several studies used regressions to examine
the effect of changes in this variable on financial markets.

combining a 3-equation macro model with a TSM using quarterly data from 1995-2003. To
assess the effect of particular actions, they regress the expectations and estimated term premia
effects on CAB and BOJ purchases of Japanese government bonds (JGBs). Increases in CAB
modestly reduced medium and long-term JGB yields by signaling markets that the BOJ would
keep rates near zero for longer than previously expected, but purchases of JGBs had insignificant
and even negative effects. Ito (2014) similarly regresses 10-year yields, the 10-/2-year yield
spread, the exchange rate and inflation expectations on sets of monthly regressors that include
measures of the monetary base and dummies reflecting phases of BOJ policy, from 1999:01
through 2014:03. These regressions imply that expanding the monetary base faster than GDP
grows lowers long rates, flattens the yield curve and tends to depreciate the JPY, although it does
not consistently affect inflation expectations. Ito (2014) concludes that QE is effective through
long rates and currency depreciation.

A difficulty with such low-frequency regression studies is that they assume that the effects of
UMP come through reserve change. If UMP announcements have their effects through asset
prices, which change immediately with expectations and precede reserve changes, then the
regression will be misspecified and macro effects may even precede the independent policy
variable.

Japan’s fight against deflation motivated more general international research on the problem
of deflationary shocks putting a floor under real interest rates at the ELB. Bernanke, Reinhart,

The authors found mixed evidence for Japan, however. An event study of the BOJ’s zero-interest-rate policy (ZIRP) and QE policy found little evidence that the BOJ announcements reliably affect policy expectations. The term structure model predicted higher long yields for Japan than were actually observed, suggesting that the BOJ policies did reduce long yields somewhat.

Bernanke, Reinhart, and Sack (2004) conclude by cautioning that despite the evidence that UMP affects yields, output and prices, that UMP measures are insufficiently well understood to be relied upon and thus prevention — not cure — of a deflationary spiral should be a priority.

Two papers explicitly use financial theory to look at the BOJ’s UMP. Kimura and Small (2006) observe that JGBs should be valuable hedges against business cycle risk. By purchasing JGBs, the BOJ removes these hedges from the public’s portfolio and should raise the price of similar high-grade bonds. But it is unclear what effect such purchases will have on riskier assets, such as low-grade bonds and equities. Consistent with this theorizing, Kimura and Small (2006) show that BOJ QE reduced credit spreads for high-grade bonds but raised stock risk premia and the credit spreads on low-grade bonds. The authors conclude that there are reasons to be cautious about the effects of large asset purchases.

Bank intermediation through banks is very important in the Japanese economy. Much of the literature evaluating the impact of UMP on financial markets looks specifically at its effect on banks. Expansionary UMP announcements should increase bank equity prices if markets believe that the programs will improve the economic outlook and the profitability of financial institutions. Researchers have examined whether BOJ UMP affected the price of bank stock, bank profitability, and bank lending.

A particularly serious banking problem for Japan in this period — and for many countries later after the financial crisis — was the banking practice of extending subsidized credit to failing firms to avoid recognizing losses on the loans (Hoshi 2006; Caballero, Hoshi, and
Kashyap 2008). This practice tied up capital and workers in failing industries and even hindered productive firms by forcing them to compete for workers and customers with failing firms.

Kobayashi, Spiegel, and Yamori (2006) study the effects of 10 BOJ policy announcements on 87 Japanese bank and 49 firm equity values from March 2001-2004. Expansionary QE events systematically raised bank equity prices but raising the ceiling on long-term JGB purchases had particular impact. Cross-sectional evidence indicates that the BOJ QE program reduced the borrowing advantage of stronger banks, thereby raising the stock prices of weaker banks and the prices of firms doing business with those weaker banks.

The effect of UMP on bank equity values is informative about bank profitability but doesn’t directly tell us about effects on bank lending, which is important for the rest of the economy. The bank lending channel of monetary policy claims a special role for banks in monetary transmission, because banks are the only institutions that can mediate between certain types of lenders and borrowers. Therefore, one potentially important way that monetary policy can affect the economy is by influencing the availability and cost of funds for banks.

The BOJ’s record with UMP from 1999-2006 appears to be mixed, at best. The long period of deflation in the 1990s had ingrained expectations and the BOJ’s measures did not convince markets that it was able and willing to combat inflation (Ito and Mishkin (2006)). One potentially important factor in this unsatisfactory performance was the BOJ’s purchasing strategy. McCauley and Ueda (2009) explore the tension between debt management and monetary policy in the context of U.S. debt management of the 1930s and Japanese debt management of 1999-2006. These authors make the important point that the BOJ’s JGB purchasing rule tended to purchase bonds of relatively short remaining maturity. As a result, the maturity of the BOJ’s portfolio actually declined from over five years in 2001 to less than four years in 2005.

To study a banking channel for BOJ policies, Bowman et al. (2015) perform a Kashyap and Stein (2000) type analysis to determine how lending by individual banks responds to monetary shocks. Bowman et al. (2015) show that the BOJ’s QE liquidity injections stimulated bank lending to a small but statistically significant degree, particularly for weaker banks, using data from 2000 to 2009. Although reduced interbank lending in response to BOJ injections mitigated the benefits, the modest success of such injections suggests that some weaker banks were liquidity constrained.

---

45 To study the bank lending channel of U.S. monetary policy, Kashyap and Stein (2000) use a 20-year quarterly panel with data on every insured commercial bank in the United States to examine how monetary policy affects lending by individual banks. They study whether monetary policy increases lending more for banks with greater lending constraints, that is, less liquidity. More liquid banks should be less affected by contractionary monetary policy shocks. Kashap and Stein (2000) first estimate each bank’s lending sensitivity to liquidity constraints and then examine how those time-varying sensitivities vary with monetary policy measures.
Research on the early Japanese experience with UMP offers mixed evidence for positive effects in financial markets. Nominal interest rate reductions and asset purchases probably helped stabilize the financial sector and stemmed deflation but they have also encouraged the ever-greening of non-performing loans, significantly prolonging adjustment.\textsuperscript{46} Readers seeking to understand the Japanese experience in 1999-2006 should read Ugai (2007), who surveys the empirical literature on Japanese UMP during this period, finding mixed conclusions on its effectiveness.

4.5 \textbf{Federal Reserve and Bank of England asset purchases}

As discussed in Section 3, the Fed and the BOE began to purchase long-term bonds within months of the worst of the financial crisis in the autumn of 2008. These asset-purchase programs have been some of the most important and most researched UMP. Because of similarities in their design, which sought to broadly stimulate their respective economies, this subsection will jointly consider research into Fed and BOE asset purchases.

4.5.1 \textit{U.S. Treasury, housing and corporate bonds}

The seminal event study on Fed asset purchases was Gagnon et al.’s (2011) research that found that the first Fed 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 offered Gagnon et al. (2011) an 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.\textsuperscript{47} To study the effect of QE1, Gagnon et al. (2011) examined how 23 UMP events from November 25, 2008 to February 17, 2010, affected 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. The authors compared the results from this “baseline event set” to those from a larger set of announcements, denoted the “baseline + all FOMC event set.”

Table 2, which is reproduced from Gagnon et al. (2011), shows that both event sets imply very substantial yield (or premia) changes during the set of UMP event days. The 10-year Treasury yield fell by 91 b.p. over the baseline event set and 55 basis points over the “all event” set. One interpretation of that disparity is that expectations of further QE were reduced during

\textsuperscript{46} Lenders are said to “evergreen” loans when they provide subsidized loans to insolvent firms to avoid having to admit losses.

\textsuperscript{47} Researchers on QE1 often assume that it was (almost) entirely unanticipated but McInish, Neely, and Planchon (2017) show intriguing evidence that short investors in the bond market were able to outpredict the marginal spot market investor in anticipating yield changes caused by Fed actions.
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 UMP announcements reduced not just the riskless 10-year yields but also default and prepayment risk premia.

Despite the fact that the FOMC explicitly stated that the fed funds rate would remain low for “some time” (12/16/2008) and “an extended period” (3/18/2009), the 2-year Treasury rate fell by only 34 and 1 basis points over the baseline and “all event” sets, respectively, from a level of only about 1 percent. The authors interpret these declines as indicating only modestly reduced expectations of future short rates, implying minimal signaling effects. The 10-year swap rate fell substantially in both the baseline (101 b.p.) and “all event” (75 b.p.) sets, but Gagnon et al. (2011) did not interpret these falls as “signaling” effects.

The authors interpreted the fall in the 10-year term premium, in both the baseline (71 b.p.) and “all event” (47 b.p.) sets, as evidence of portfolio balance effects. Thus, the study found the UMP policy actions reduced long-term, private (MBS and corporate) term premia by 30-100 b.p. through the portfolio balance channel, improved liquidity and reduced prepayment premia. We would generally agree with Gagnon et al. (2011) interpretation of their evidence but we would also argue for the presence of non-trivial signaling effects. We believe that declines in swap rates indicated some signaling and the already low level of short-term yields probably inhibited greater declines.

In addition to studying Fed UMP announcements, Gagnon et al. (2011) also studied the initial rounds of BOE asset purchases, to which they ascribe similar effects as those found for the Fed’s QE1. Joyce, Tong, and Woods (2011) more fully describe the design and impact of the BOE asset purchases in 2009-2010. Reactions to monetary policy events suggest that these announcements reduced gilt yields by about 100 basis points, which the authors equate to a sizable 150-300 basis point cut in short rates. The authors cite other research as indicating that these financial effects translated into modest effects on output and then inflation.

Although it was sometimes not emphasized in early studies, an important stimulatory component of early asset purchases was the fact that it lowered ex ante, real, long-term interest

48 Greenlaw et al. (2018) recently restate this point in arguing that UMP asset purchases effects are smaller than often claimed.
49 In a private communication, Matt Raskin explained that the Gagnon et al. authors were reluctant to interpret changes in the swap rate as changes in expected future short rates because they feared that large and systematic changes in risk premia over the announcement windows would contaminate such swap-rate changes.
50 During its first two rounds of asset purchases —March 2009 to January 2010 and October 2011 to May 2012 — the BOE purchased bonds worth £200 billion (QE1) and £125 billion (QE2), respectively. The first set of BOE asset purchases (2009-2010) was similar in size to the Federal Reserve’s QE1 when measured as proportions of their respective economies. That is, each program purchased bonds valued at about 11-13 percent of their respective nominal GDPs.
rates by raising inflation expectations. A popular way to examine changes in expected inflation at high frequencies — in a manner suitable for event studies — is to use market expectations of “break-even” inflation constructed from either 10-year nominal and Treasury Inflation Protected Securities (TIPS) yields or inflation swaps. While the levels of these measures doubtless have risk premia embedded in them, event study researchers hope/assume that changes in the level of these measures are informative about changes in inflation expectations. Guidolin and Neely (2010) examine the 2-day changes in “break-even” inflation expectations constructed from 10-year TIPS to three Fed QE1-era announcements, showing that break-even inflation increased by 34 b.p. in total over the three events, suggesting that QE might have limited ability to influence inflation expectations. Farmer (2012b, 2013) argues graphically and from 1-year inflation swaps that the Fed’s QE1 stopped deflationary expectations in their tracks, which was good for real activity.

### 4.5.2 Local Supply Effects

Section 4.2 distinguished between two types of portfolio balance effects: duration removal and local supply (or local scarcity). One can distinguish these effects in the data because duration removal should affect yields of the longest duration/maturity securities while local supply affects should most affect the prices of nearest-substitutes, i.e., securities with the closest maturity to those purchased.

Because financial markets are forward looking, most asset purchase transmission channels have nearly all of their effects at the time of the announcement, therefore most research has concentrated on announcement effects. But because central banks don’t choose specific issues until it is time to purchase securities, it is very possible that local supply effects will have additional impact at transaction time as markets learn purchasing strategies, which specific issues will be purchased, the capacity of market makers to handle inventory changes and how much price adjustment will be needed to rebalance portfolios.

D’Amico and King (2013) conduct a seminal study of central bank (Fed) QE1 asset purchases on local supply with security-level data on Treasury prices and quantities to investigate the existence of local supply/scarcity effects of QE1. The heart of their study is a cross sectional regression of changes in bond prices (returns) for all CUSIPS on measures of Fed purchases of bonds of nearby maturities, along with the duration of the dependent bond between March 17, 2009 and October 30, 2009. That is, the regressors to explain stock yield changes for a given security were the quantity of the Fed purchases of that specific bond, near substitutes (bonds within 2 years of the dependent bond’s maturity), mid-substitutes (bonds within 2-6 years of the dependent bond’s maturity), far-substitutes (bonds having maturity more than 6 years different than the dependent bond) and a quadratic in the duration of the dependent bond variable. Because the New York Desk had authority over purchase strategies, making the specific issues endogenous to their pricing, the authors use an instrumental variables technique with ex ante bond characteristics as instruments to address potential endogeneity biases. The
authors do a similar exercise with 57 Fed transactions to study flow effects. D’Amico and King (2013) find the Fed’s $300 billion Treasury QE1 purchases produced a stock local-supply reduction of 30 basis points in Treasury yields across the yield curve, and as much as a 50 basis point reduction for yields of bonds with 10–15 years of remaining maturity. In addition, there was a flow effect on specific issues from actual transactions of 3.5 basis points. A significant issue in this study is how much effect the omission of Fed MBS purchases — due to data availability and continuity with the literature — had on the results. Given that the Fed’s MBS-only announcement of November 25, 2008 had significant effects on the Treasury market, one might be concerned about the omission.

Meaning and Zhu (2011) initially perform an event study, showing that long yields in the U.S. and U.K. fell at UMP announcements but that the initial rounds of announcements in 2008-2009 had larger impact than later rounds. The authors follow that with local-supply stock analysis, a la D’Amico and King (2013) to study time variation in the effects of the Fed’s QE1 and QE2 (November 2010 to June 2011) and the BOE’s APF1 (March 2009 - January 2010). Consistent with D’Amico and King (2013), the authors conclude that both local supply and duration removal reduced the nominal term premium considerably. But the Fed’s QE1 produced larger announcement and local supply effects than QE2, per unit of purchase size. The authors speculate that the switch to purchasing Treasuries in QE2, rather than MBS and Agency debt, might have contributed to the reduced effect. An alternative explanation is that the later effects appeared to be smaller because later purchases were less surprising.

Using data on individual gilts, Joyce and Tong (2012) conduct both a high frequency event study on the initial stages of BOE asset purchases from March 2009 to January 2010 and a panel regression with data from January 2009 to April 2010 to investigate local supply effects while controlling for fiscal and macro news with appropriate regressors. Such controls are particularly appropriate when one is explaining the behavior of yields over many months, rather than in a window of a few hours around an announcement. With such controls, the panel regression shows that BOE QE announcements reduced the average level of the yield curve by approximately 100 b.p., with particularly strong effects on longer maturities of 15 and 20 years. The authors interpret these declines as coming from both removal of duration and stock local supply effects. Markets responded heterogeneously to the announcements, taking varying lengths of time to incorporate the news into prices. Prior to each reverse auction, eligible and ineligible gilt yields declined by 2.5 basis points and 1.5 basis points, on average, respectively, indicative of flow effects of local supply. This auction-specific effect tended to decline over time, presumably as participations learned about the function of the BOE asset purchase program and auctions contained less news.

51 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 particularly strong effects because it eased financial stresses.
These first papers — D’Amico and King (2013), Meaning and Zhu (2011), and Joyce and Tong (2012) — estimated local supply effects with total purchases per security but market reaction should be based largely on the unexpected purchases per security. That is, the total quantity purchased probably overestimated the shock and therefore underestimated the local supply price reaction.

To construct expected and surprise components of five UMP announcements from 2008-12, Cahill et al. (2013) use Desk Primary Dealer Survey and information from Primary Dealer market commentaries, announcement details about the intended distribution of purchases/sales across maturity sectors and intraday data on price quotes for all Treasury CUSIPs over the sample. That is, the authors construct expectations for purchase quantities for each bucket in the yield curve, which is novel and useful. With this procedure, the authors attributed most UMP-induced variation in Treasury yields to local-supply and duration-risk ‘shocks.’ Averaging across all 5 events in the study, a $100 billion surprise on the 10-year nominal Treasury yield reduces yields by about 5 b.p. from the duration-risk effect and 4 b.p. from the local-supply effect. Controlling for pre-announcement market expectations removes any evidence that the impact of the channels has declined over time.

Noting that it has become more difficult to evaluate the impact of QE policies as markets learned to anticipate them, McLaren, Banerjee, and Latto (2014) exploit the markets’ reaction to unpredictable operational changes in the distribution of purchases across the yield curve to identify the local supply effects of BOE asset purchases on yields for announcements in March 2009, August 2009 and February 2012. The authors construct surprise purchases for each gilt sector from total expected purchases from a Reuter’s survey of private-sector economists, along with the total actual purchases for each sector and the operational changes to the distribution of purchases. The estimated local supply effects are consistently very large across announcements, accounting for about half of the total impact on gilt yields and they are passed through to index-linked gilt and investment grade corporate yields, suggesting that they are not merely artifacts of gilt-market frictions. Neither do local supply effects reflect illiquidity or uncertainty. Although the method effectively identifies local supply effects, it does not provide information about other channels so it cannot evaluate the total purchase impact.

After first reviewing how the BOE’s bond purchases affect the economy and evaluate the impact of the BOE’s QE1 and QE2 — March 2009 to January 2010 and October 2011 to May 2012 — on financial markets, Joyce, McLaren, and Young (2012) apply the procedures of McLaren, Banerjee, and Latto (2014) to identify the local supply effects of BOE asset purchases on yields. The strengths of the local supply channel are similar over time/events, indicating approximately constant effects, at least for this channel. The authors conjecture that the EU debt crisis could have reduced the per-pound impact of the BOE’s QE2 announcements on corporate bond price and the FTSE index. The author suggest that it is difficult to draw firm conclusions about the price impact of the BOE’s QE1 vs. QE2 but there is no hard evidence that the price impact has declined.
Careful investigations with high frequency data on individual bonds strongly support the idea that both local supply effects and duration effects of bond purchases reduce sovereign yields in the U.S. and UK. The largest effects, by far, are stock effects associated with announcements, but there are also very modest flow effects associated with transactions. The two channels seem to have similar effects and — after controlling for expectations — the effects do not seem to have diminished over time. The use of high-frequency data and creation of “purchase surprises” through survey evidence and procedural variation proved to be useful in precisely measuring these effects. An unexplored issue is the extent to which purchases of other assets, e.g., MBS, could affect sovereign yields through a local supply effect.

4.5.3 Housing bonds

Housing GSE debt and MBS accounted for more than 80 percent of QE1 assets purchased. Because of the FOMC’s emphasis on housing, researchers have extensively examined the behavior of related bonds in response to UMP. Although Gagnon et al. (2011) studied a wide variety of bond yields, including MBS and corporate bonds, 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 QE1 announcements significantly reduced MBS yields and mortgage rates. They argue that Fed purchases of agency MBSs drove the decline in mortgage rates through the “safety channel” while purchases reduced agency MBS yields through the “mortgage prepayment risk” channel. The authors also contend that QE2 Treasury purchases reduced both mortgage and MBS yields, but with much smaller effects on MBS yields. They interpret the smaller (scaled) effect as due to lack of direct reduction in mortgage market prepayment risk. In fact, the authors find that the signaling channel, rather than elements of the term premium, fully account for the fall in MBS yields around QE2 announcement dates.

Fuster and Willen (2010) use a complementary event-study approach to investigate how the Fed’s purchase of MBS affected U.S. households’ mortgage market behavior. Using detailed micro data, the authors show that announcement of the agency MBS purchases on November 25, 2008 increased searches, applications, and acceptances in the primary loan market. In addition, a higher percentage of applications became originated mortgages. The increases in these quantities persisted and peaked again after the big March 18, 2009 QE1 announcement. The vast majority of those applications and originations were refinancings, however, as the purchase mortgage market was little affected over the sample.

The authors also show that LSAP announcements reduced interest rates for borrowers in a heterogeneous manner. Borrowers with poor credit (FICO scores) got smaller rate reductions than did those with good credit and the announcements apparently shifted refinancing activity shifted toward high-FICO borrowers. Fuster and Willen (2010) argue that increased fees —
called Loan-Level Price Adjustments or Postsettlement Delivery Fees — that GSEs charged low-FICO borrowers, which exactly coincide with the first LSAP announcement, explain the shift toward high-FICO borrowers. Because the borrowers who refinanced were mostly high quality and not credit constrained, the authors argue that the program probably did not stimulate consumption. Further the authors found no evidence of increased search for houses or increases in loan amounts. That is, Fuster and Willen (2010) are skeptical of a substantial impact on the purchase market. The exploration of this topic is graphical, informal and complicated by seasonalities in the housing market. One might be concerned that the method of analysis had low power to detect modest changes.

It is possible that Fed MBS purchases can destabilize yields through the negative convexity characteristic of MBS. MBS duration rises when interest rates rise, which could generate positive feedback to yields as agents holding MBS dump their bonds as yields rise. That is, MBS convexity could and perhaps has contributed to destabilizing U.S. bond markets at times. Hanson (2014) develops a model that features investors with very limited short-run risk tolerance, which produced large fluctuations in bond risk premia. The implication for QE is that if shocks to the quantity of duration have significantly affected term premia in the past, then central bank purchases of duration could presumably reduce term premia.

Di Maggio, Kermani, and Palmer (2018) complement the extensive literature on price (yield) reactions to asset purchases by investigating how the composition of Fed asset purchases influences credit allocation across sectors using a mortgage-market data set. That is, they focus on credit quantities rather than prices. Because quantities — such as mortgage originations — take time to adjust after asset purchase announcements, the authors do not use short-run event studies but longer term analysis, including regressions, that exploits the fact that only some types of MBS were eligible for Fed purchase and the Fed purchased these MBS in QE1 and QE3 but not QE2 or the MEP. Mortgages that are eligible for Fed purchase are those that meet the GSE standards for securitization. The total loan value of each such eligible mortgage, called “conforming mortgages,” is capped and the loan-to-value ratio must be less than 80 percent.

Consistent with much other work, Di Maggio, Kermani, and Palmer (2018) report that QE1, which entailed significant MBS purchases, depressed mortgage rates by more than 100 basis points but reduced rates on non-conforming jumbo loans much less, raising the jumbo-conforming spread by a whopping 40-50 basis points. QE3 also increased the conforming-jumbo spread but much less than QE1. In contrast, QE2 and the MEP — which did not purchase MBS — reduced mortgage rates without changing the conforming-jumbo spread. In other words, Fed MBS purchases had a particularly strong impact on mortgages eligible to be securitized into MBS. The mortgage-origination story is very similar. QE1 doubled GSE-guaranteed mortgage originations but only raised non-conforming mortgage origination by 10%. QE3 also showed differential jumbo-conforming differences but they were much smaller. The authors explain this QE1/QE3 difference with a measure of bank distress, which was much lower in the QE3 period. In contrast, QE2, which purchased only Treasures, did not differentially affect conforming/ non-
From a macro perspective, the authors estimate that QE1 increased refinancing by $100 billion in its first six months, which increased consumption by $13 billion through lower mortgage costs. The authors conclude that QE works through a mortgage-refinancing channel and it disproportionately benefits consumers eligible for a conforming mortgage. The authors also suggest directing funding for lending to credit-constrained consumers and institutions.

Evidence from micro data indicates that Fed MBS purchases substantially increased mortgage refinancings but not mortgages in the purchase market. These purchase programs had heterogeneous effects across consumers, depending on their credit worthiness and whether their mortgage was conforming.

4.5.4 Corporate bonds

Unlike Treasury debt, Agency MBS and Agency debt, corporate bonds are not effectively backed by U.S. government and therefore their yields reflect the risk of default. UMP can reduce the default risk by stimulating the economy, improving macroeconomic and financial conditions and thereby reducing the probability of corporate bankruptcy. 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 central bank asset purchases can lower corporate yields by raising the prices of assets that financial intermediaries own and thereby increasing the capital of those intermediaries and increasing their capacity to bear risk. Very high grade corporate bonds may be influenced by the “safety channel,” changes in the supply of very safe assets. Finally, expectations of future Fed policy and duration risk can affect corporate yields in the usual ways through signaling and portfolio balance channels. Researchers have studied these possible transmission channels of unconventional policy with several different methods, including those theories that place financial intermediaries at heart of UMP transmission of earlier, which we discussed in Section 2 (Gertler and Karadi 2011, 2013; and Gertler and Kiyotaki 2010).

In their event-study, Krishnamurthy and Vissing-Jorgensen (2011) infer the importance of the default risk channel with data on corporate yields and credit default swap (CDS) rates. Contrasting the impact of UMP announcements on high- and low-grade corporate bond yields permits one to measure default risk while the use of CDSs permit one to infer the market’s estimate of the likelihood of default. Corporate yields adjusted for CDS rates filter out the default risk channel, and thereby isolate the effects of other channels.

Bhattarai and Neely thank Marco Di Maggio for an updated draft of the paper and personal communications about the distinction between their QE1 and QE3 results.
Krishnamurthy and Vissing-Jorgensen (2011) find that corporate yields fall significantly around QE1 announcement dates and CDS rates on low grade bonds also fall dramatically. This suggests that QE1 played an important role in decreasing default risk or the default risk premium in the economy. The fact that UMP announcements reduce high-grade corporate yields that have already been adjusted with CDS rates to remove the default risk channel suggests a role for the safety channel. Analysis of these adjusted rates indicates that the signaling channel cannot fully account for effects on some high grade bonds. For QE2, 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.

From their work on MBS purchases and corporate yields, Krishnamurthy and Vissing-Jorgensen (2011) draw two policy conclusions: Central banks should also purchase corporates and MBS because these have the greatest impact on non-sovereign markets and asset purchases have their greatest effect by reducing expectations of future short rates, i.e., the signaling channel.

Researchers such as Gagnon et al. (2011), Joyce, McLaren, and Young (2012) and Krishnamurthy and Vissing-Jorgensen (2011) showed that Fed and BOE UMP announcements lowered yields and bond spreads, which should have lowered the cost of investment and thereby stimulated corporate bond issuance. Lo Duca, Nicoletti, and Martinez (2016) confirm this conjecture: 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.

In summary, the literature on corporate bonds indicates that Fed asset purchases, particularly MBS, have reduced corporate yields through several channels, including default and safety, and have stimulated corporate issuance.

4.5.5 Equities and equity uncertainty

Monetary policy is often thought to influence output and prices through equity markets. Expansionary policy, for example, both reduces the discount rate and increases cash flows, raising stock prices and improving balance sheets. Such equity price increases can raise consumer expenditures through the wealth effect, increase firm investment by raising Tobin’s q and reduce asymmetric information problems in lending markets. In addition, reduction in interest rates reduces firms’ payments on variable rate debt — the “floating rate channel” — which strengthens firms’ cash flows and balance sheets.
Given the importance of the topic, a number of studies have considered the impact of U.S. and U.K. asset purchase announcements and forward guidance on equity prices. Some of the early event studies looked at the effects on equity indices. Joyce et al. (2011) found that the first rounds of BoE announcements (2009-2010) had inconsistent and overall negative effects on equity prices while Neely (2015) and Wright (2012) found modestly positive effects on U.S. equities from Fed QE1 announcements. Farmer (2012b, 2013) argues that, because MBS payoffs are procyclical, their returns should be correlated with equity returns and that variation in the Fed’s MBS purchases was closely tied to the ups and downs of the stock market. Wright (2012) estimates monetary shocks as the first principal component of high frequency yield curve changes around monetary policy decisions. Regressions indicate that an unconventional shock — asset purchase plus forward guidance — that lowers 10 year yields by 12 basis points would raise the S&P 500 index prices by a little more than 0.5 percent, which is positive and statistically significant, but appears small.

To investigate the surprisingly modest impact of UMP on equity prices, Kiley (2014) posits a two equation model in which the 10-year yield and the stock return are both linear functions of the unobserved monetary policy shock. A regression of stock returns (or other asset returns) on changes in 10-year yields would produce inconsistent estimates of the coefficient on the monetary shock because both the stock return and the change in the 10-year yield are linear functions of the unobservable UMP. Kiley (2014) consistently estimates the coefficient with instrumental variables (IV), however, using the 1-quarter-ahead eurodollar, 2-year and 5-year yields as instruments for the relevant policy rate, which the 10-year yield proxies.

With data prior to 2009, this IV approach yields essentially identical inference about monetary effects on equity prices as Gürkaynak, Sack, and Swanson’s (2005) 2-factor methods, but very different impacts in the unconventional period. Kiley finds that only one monetary policy factor — not two, as in the conventional period — affects equity prices after 2008. In other words, monetary policy shocks affected equities less in the unconventional period because they moved only the medium and long ends of the yield curve, not the whole curve.

Hattori, Schrimpf and Sushko (2016) showed that UMP 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. Value-at-risk calculations imply that UMP 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.  

53 Fawley and Neely (2014) detail the literature on the impact of conventional U.S. monetary policy shocks on asset prices, including equities.
54 The risk-taking channel of monetary policy can work in two ways. If financial institutions and investors have contractual or institutional goals, such as achieving a certain nominal rate of return, low interest rates may create
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 uncertain value.

The previous studies of the impact of UMP on equities all used equity indexes, not data on individual stocks. Potentially, more information about the transmission of monetary policy is available from studying how the individual stock prices of heterogeneous firms respond to UMP shocks.

Ippolito, Ozdagli and Perez-Orive (2018) investigate the “floating rate channel” of monetary policy — the mechanical effect of floating rate debt on firm cash flow and balance sheets — with micro and stock data. The authors first describe a theoretical model before comparing the micro evidence from a conventional policy sample (2002-2008) with that from an unconventional policy sample (2009-2011). Empirically, conventional monetary expansions increase firm stock prices, especially for firms with higher levels of unhedged debt. These financially constrained firms with bank debt are much more sensitive to monetary policy.

Regressions of 4-quarter ahead investment on interest rate changes indicate that rising interest rates predicts higher investment but this change is smaller (larger) for firms with unhedged (hedged) bank debt. These regression results are much weaker in the unconventional period, suggesting that the floating rate channel doesn’t matter when short rates are more-or-less fixed at zero. Although the authors argue that the floating rate channel is an important macro channel during conventional times, they also concede that the channel has been limited during the period of UMP when short rates were pegged to zero.

In summary, UMP shocks tend to have more modest effects on equity prices than one might think because they move only the medium and long ends of the yield curve rather than the whole yield curve as do conventional shocks. Asset purchase announcements significantly reduce market estimates of tail risk but not implied volatility. The ZLB precludes an UMP effect through the floating rate channel, however.

4.5.6 Time variation in asset purchase effectiveness

Many researchers — e.g., Krishnamurthy and Vissing-Jorgensen (2011), Meaning and Zhu (2011) — have observed that early Fed and BOE asset purchase announcements produced far incentives for these agents to accept more risk to achieve those goals. In addition, low interest rates raise the discounted, risk-adjusted future payoff of a given project, making any given project more attractive. 55 High interest rates presumably (perversely) predict higher investment because interest rates are highly correlated with the business cycle.

55
larger contemporaneous effects on bond yields than later announcements. Some researchers, such as Martin and Milas (2012), have naturally conjectured that smaller announcement impacts indicate reduced effectiveness of later rounds of asset purchases. Some ascribe declining effectiveness to the normalization of liquidity conditions after the crisis or perhaps the process of markets learning that asset purchases are not effective or not persistent or even simple market inefficiency. Others would argue that the smaller contemporaneous impact of announcements in later rounds of QE did not show declining effectiveness because either non-monetary economic conditions counteracted yield changes (Joyce and Tong 2012) or market markets had learned to anticipate and price UMP into yields by the time of the later rounds of asset purchases. In other words, during later rounds, every bit of economic news influenced expectations of future policy and thus yields. Thus, markets came to better anticipate later rounds of Fed asset purchase announcements. The works of Cahill et al. (2013) and Joyce, McLaren, and Young (2012) support this latter interpretation. These papers show that controlling for the size of monetary surprises produces very similar local-supply effects of asset purchase announcements over time.

An important related issue in UMP transmission is the extent to which purchases of bonds translate to private yields, which determine private incentives to invest or consume. Kiley (2016) applied the unobserved monetary shock strategy from his equity paper to determine if Treasury yield changes have passed through to private yields (Baa or Aaa corporate) at the same rates during the conventional (1993-2008:12) and unconventional (2008:12-2012) periods. Examining the effect of the unobservable UMP shock on private yields in 30 minute windows around FOMC announcements with an IV regression, the author finds that pass-through from the 20-year Treasury to the Baa or Aaa corporate bond yield is 20 percent lower in the ZLB period. Kiley (2016) suggests that either QE relies on mechanisms, such as safety, that won’t impact private bonds (Krishnamurthy and Vissing-Jorgenson 2011, and Woodford 2012) or that UMP announcements release information that causes credit spreads to covary negatively with yields and thus reduce pass through.

The literature has found that controlling for the effect of time-varying expectations essentially eliminates most evidence that primary asset purchase effects have declined over time but pass-through to corporate yields seems to have modestly declined in later purchase rounds.

4.5.7 International bond yields

Neely (2015) used event study methods, similar to those used by Gagnon et al. (2011), to show that the Fed unconventional policy (QE1) announcements substantially reduced international sovereign bond yields and the value of the U.S. dollar on foreign exchange markets. Neely (2015) shows that foreign yields fell by 21 (43) basis points in the broad

56 Neely (2015) followed Gagnon et al. (2011) in defining two event sets: the first is a narrow event with only eight 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.
(narrow) event sets, respectively, while the USD depreciated over the broad (narrow) event sets by about 10 (6) percent. Figure 8 — excerpted from the appendix to Neely (2015) — is particularly compelling evidence of the power of UMP to move international markets. This figure shows futures price movements from 14 hours before the announcement to 18 hours after. Clearly, the March 18 announcement of large MBS, agency debt, and new Treasury purchases raised bond futures prices by 1 to 3.5 percent (top panel) and reduced the value of the dollar by 2 to 3 percent (middle panel). These jump depreciations of the USD are fairly consistent with the results of equivalent, conventional monetary policy shocks. Equity and oil prices rose by more than 2 percent in the hour following the announcement, which is consistent with the interpretation that the announcement increased expected growth (bottom panel). The QE1 announcements appear to have moderately raised stocks and oil prices, which suggests that the policy announcements did not reduce yields by lowering expectations of real growth. The author shows that the estimated effects of the Fed’s UMP announcements on international yields are consistent with the quantified predictions of a portfolio balance model, calibrated to historical data. Neely (2015) concludes that unconventional policy can reduce international long-term yields and the value of the dollar even at the zero bound.

Neely’s (2015) findings on international asset markets are consistent with those of Ait-Sahalia et al. (2012), who found positive international spillovers from early domestic financial market interventions and with Rogers, Scotti, and Wright (2014), who compared UMP shocks from the Fed, BOE, ECB and BOJ, finding that U.S. shocks exhibited the greatest international spillovers.

Neely (2015) analyzed how Fed bond purchases affected yields in developed bond markets and major exchange rates. In complementary work, Bowman, Londono, and Sapriza (2015) examine the effects on yields and exchange rates with emerging markets. The latter authors use the identification-through-heteroskedasticity methods of Rigobon (2003) and Wright (2012) in a daily VAR(1) to identify the effect of U.S. monetary policy shocks on sovereign bond yields, exchange rates and stock prices with data from 17 emerging market economies from January 2006 to December 2013. U.S. monetary policy shocks generally lower 10-year EME yields but the effect is often not statistically significant. If one permits delayed effects — often delayed for days or weeks — Bowman, Londono and Sapriza (2015) find statistically significant effects for many countries. At the aggregate level, a 25-b.p. expansionary policy shock to U.S. 10-year yields reduces EME sovereign yields by about 20 basis points. The VARs imply statistically insignificant effects on U.S. equities and the USD vs. an EM currency basket. An event study confirms the inference from the VARs. The multiplicity of tests gives reason for concern about the significance of individual results, however.

The authors go on to investigate the cross-sectional determinants of changes in yields for the EMEs using a panel regression with monthly data. Riskier countries respond more strongly to U.S. variables and the cross-sectional heterogeneity in responses is greater to the U.S. spread than to the U.S. 10-year yield change.
Fed asset purchases appear to have had substantial impact on exchange rates and the sovereign bond yields of developed countries but it is harder to find consistent, statistically significant impacts on the exchange rates and yields of emerging markets.

4.5.8 Inferring monetary information from multiple assets

A series of relatively recent papers have employed multiple assets in examining the effects of UMP on asset prices. Their purposes are subtly different, however. Claus, Claus, and Krippner (forthcoming) extend previous work on estimating monetary shocks with multiple yields to the use of six different assets, exploiting the information in all their variances to identify monetary shocks. Cieslak and Schrimpf (2018) infer the type of information in major central bank news from the covariation between stocks and bond yields, then characterize patterns in the data. Inoue and Rossi (2018) extend previous work on multi-dimensional monetary shocks to consider changes in the whole yield curve as an N-dimensional shock. All three papers compare their results between conventional and unconventional periods.

Gürkaynak, Sack and Swanson (2005) provided a novel view of monetary policy by defining 2-dimensional monetary shocks with the first two principal components of the yield curve. In principle, however, monetary shocks should affect all asset prices and one might exploit this information to develop better measures of such shocks. Claus, Claus, and Krippner (forthcoming) uses daily prices of six assets: 10-year Treasury yield, Moody’s Aaa yield, gold, S&P500 index, Wilshire REIT (real estate investment trust) total index, GBP/USD, to quantify U.S. monetary policy shocks in both conventional and unconventional periods, with a daily event study from February 1996 to January 2016. The conventional/unconventional break is September 12, 2008. The authors estimate the impact of monetary shocks on asset prices over the two subsamples using the Kalman filter on a latent factor model in which the monetary shocks are identified through the higher variance of asset returns on monetary policy announcement days.

Monetary effects are consistently signed during both samples, despite the lower bound in the later period, but monetary shocks have larger impacts on asset prices during the unconventional sample. A bootstrapping exercise implies that this UMP effect is due to larger UMP shocks for Moody’s Aaa yield, S&P500 index, Wilshire REIT total index, and GBP/USD and to both larger shocks and greater sensitivity for the 10-year Treasury yield and gold. The authors conjecture that the unconventional period might feature different transmission channels or more risk aversion. Adding a 2-factor shadow short rate to the asset price set does not substantially change inference. Claus, Claus, and Krippner (forthcoming) conclude that central banks appear to be able to affect asset prices even at the lower bound and that the authorities should be conscious of potentially having larger asset-price effects with UMP.

Central bank monetary events, including policy decisions, press conferences, minutes releases and inflation reports, can convey multiple kinds of information. They can convey the central bank’s view of real activity or changes in risk tolerance, or a deviation from a perceived
monetary policy rule. Cieslak and Schrimpf (2018) infer categories and signs of these types of information conveyed by types of central bank events. A simple model implies that monetary shocks — i.e., deviations from the central bank reaction function— move stock returns and yields in the opposite direction (negative covariance). “Growth” and “risk” shocks move stock returns and yields in the same direction (positive covariance) but growth (risk) shocks have bigger effects on short (long) yields. That is, growth and risk shocks are arguments to the central bank reaction function while monetary shocks are deviations from that function.

Cieslak and Schrimpf (2018) calculate the realized covariances between equities, short and long yields that follow events in an extensive database of central bank events — monetary policy decisions, UMP events, minutes releases, press conferences and inflation reports — for the Fed, the ECB, the BOE and the BOJ, over 1998-2018. Events that intuitively seem related to monetary, growth or risk news produce realized covariances that correspond to the definitions of monetary, growth or risk shocks, respectively. The direction of the shocks also accords with intuition of the information content of the episode.

Different types of central bank events produce different types of news. Fed and ECB monetary policy decisions (e.g., FOMC statements) generally produce monetary news over the whole sample but communication events — i.e., press conferences, minutes releases and inflation reports — generally produce growth and risk news prior to 2013. After 2013, however, Fed, ECB and BOE stock-bond yield covariances switch sign, becoming negative during communication events, indicating a switch to the dominance of monetary news, consistent with the Fed’s move toward tapering/normalization in 2013.

Inoue and Rossi (2018) compare the dynamic effects of both conventional (1995:01-2008:10) and unconventional (2008:11-2016:06) monetary policy on exchange rates. The paper extends the Gürkaynak, Sack and Swanson (2005) two-dimensional view of conventional monetary policy to model monetary shocks as a shift in a function, i.e., the whole yield curve. The authors refer to this new identification procedure as a “functional shock”. The explicitly multi-dimensional nature of the shock differentiates this method from previous works which separately calculate asset price responses to a set of interest rates or factors.

To model the impact of monetary policy shocks on exchange rates, the authors estimate 2-lag VARs on 5 daily zero-coupon yields and one of each of four exchange rates (EUR, GBP, CAD and JPY vs. USD) over two subsamples, 1995:01-2008:10 and 2008:11-2016:06. This VAR produces impulse response functions for the effect of each yield on the exchange rate. The authors model the dynamic impact of a monetary event on exchange rates with a weighted linear combination of yield changes where the weights are impulse response coefficients of each exchange rate to yield shocks. In the notation of Inoue and Rossi (2018), the h-period ahead impact of a monetary shock on day, t, on exchange rate, i, is given by the weighted sum of the yield changes on day t.
\[
\frac{\partial \Delta s_{t,t+h}}{\partial \varepsilon_t^{mp}(\tau)} = \sum_{\tau=1}^{M} c_{\tau}^{(h)} \Delta y_{t,t}^\tau
\]

where \( \Delta s_{t,t+h} \) is the exchange rate, \( i, \) at time \( t+h, \) \( \varepsilon_t^{mp}(\tau) \) is the monetary shock to maturity \( \tau \) at time \( t, c_{\tau}^{(h)} \) is the h-period ahead VAR impulse response of the yield with maturity \( \tau \) on exchange rate \( i \) and \( \Delta y_{t,t}^\tau \) is the exchange rate change on the date of a monetary policy announcement. By tracing out movements over horizons from 1 to \( H, \) one can characterize the dynamic impact of a particular monetary shock on an exchange rate.

The empirical results indicate that both the sign and magnitude of UMP effects on exchange rates are similar to those of conventional monetary policy. In either case, monetary easing depreciates the country’s exchange rate. There is also evidence of Dornbusch (1976) overshooting at the daily frequency, which is at odds with monthly VAR measures.

By accounting for the movement of the whole yield curve, the authors incorporate changes in expectations of future policy and risk into their monetary shock measure. Monetary shocks exhibit substantial heterogeneity over time and because the shocks (vectors of yield changes) will generally be linearly independent — i.e., not be proportional to each other — each shock will have a unique dynamic impact.

### 4.5.9 International portfolio flows

The previous section discussed findings that Fed bond purchases changed relative international yields but such transactions could also change quantities. By changing relative international interest rates and credit conditions, UMP changes the relative attractiveness of international investment and presumably causes investors to change investment patterns. Ceteris paribus, lower yields in the country employing UMP should push investment abroad but, on the other hand, a depreciated domestic currency should make domestic assets more attractive. Fratzscher, Lo Duca, and Straub (2017) use a novel database to investigate how both announcements and transactions of the Fed’s QE influenced daily international portfolio flows in the U.S. and in 52 other countries. Using data from 2008 through 2012, the authors regress portfolio flows for an asset class in a particular country or groups of countries on QE announcement dummies, Fed Treasury purchases, a variable measuring Fed liquidity operations and additional controls, such as macro surprises and the VIX. While QE1 policy announcements and transactions induced investors to rebalance toward riskier asset, mostly U.S. equities, QE2 and QE3 announcements and Treasury purchases triggered flows to EMEs. The authors conjecture that lower macro uncertainty during QE2 and QE3 produced the greater flows to EMEs rather than U.S. equities. The authors note that flow effects of transactions are consistent with D’Amico and King’s (2013) finding of transaction effects on prices.
Several sets of authors have combined TSMs with event studies to assess the relative contributions of signaling and portfolio balance effects of Fed and/or BOE asset purchases. Changes in the model-implied expected overnight interest rate are interpreted as signaling while the difference between the announcement impact on long yields and the model-implied, expected overnight interest rate would be taken as the announcement’s portfolio balance effect.

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 modest. In contrast, Bauer and Rudebusch (2014) and Christensen and Rudebusch (2012) claim that the signaling channel accounts for 30–65% of the total Fed QE1 impact, rather than the 30% suggested by Gagnon et al.’s (2011) analysis. A potentially key difference between the two sets of estimates is that Bauer and Rudebusch (2014) and Christensen and Rudebusch (2012) correct for small-sample bias in the time series process for the yield curve factors in estimating the TSM, which will increase the estimated persistence of the latent factor underlying the term-structure process and thus increase the estimated persistence of an expansionary shock to the level of the yield curve, producing more signaling.\(^\text{57}\)

Applying their bias-corrected TSM to study long-yield changes around seven U.K. QE1 announcements, Christensen and Rudebusch (2012) attribute the entire decline in U.K. 10-year yields to a lower term premium, in sharp contrast to that for their U.S. results, where they assign 50% role to the signaling channel. In fact, Christensen and Rudebusch (2012) find that expected future U.K. short-term interest rates actually increased over the announcements, probably from increased expected growth. The result that declines in term premia were important for the U.K. QE1 policies are consistent with those in Joyce et al (2011).

The “negative” signaling effects found by Christensen and Rudebusch (2012) on U.K. data appears to exemplify the tendency of TSMs to overstate term premia effects and understate expected short rate effects. Bauer and Rudebusch (2014), Christensen and Rudebusch (2012), Bauer and Neely (2014), and Hattori, Schrimpf, and Sushko (2016) all emphasize that changes in expected short-rates should be viewed as conservative estimates of signaling effects. Successful UMP reductions of term premia will raise expected growth and therefore raise expected future short rates. Thus, successful portfolio balance effects will appear to produce negative signaling effects.

Bauer and Neely (2014) analyze the channels through which the Fed’s UMP announcements from 2008 to 2012 (QE1, QE2, MEP, and QE3) influenced U.S., Canadian, German, Australian

---

57 A TSM typically models 1 to 3 yield curve factors — level, slope, curvature — with a VAR. The short-term interest rate and the vector of prices of risk are functions of these factors and the SDF is a function of the prices of risk. The OLS parameter estimates of the VAR that governs the factors are biased downwards, as is usual for the coefficients of a persistent autoregressive process.
and Japanese sovereign bond yields with several TSMs. The characteristics of each country’s bonds explain the importance of estimated signaling vs. portfolio balance channels. That is, countries whose yield curves were ordinarily sensitive to conventional U.S. monetary policy shocks also exhibited large UMP 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 from UMP shocks. For example, Canadian yields react more strongly to conventional U.S. monetary policy surprises than do those of any other non-U.S. country in our sample and U.S. UMP shocks produce a strong signaling effect on expected Canadian short rates. In contrast, the yields of Australia and Germany, whose bond returns covary moderately more with U.S. long bond returns but whose yields react less strongly to U.S. conventional monetary shocks than do Canadian yields, show greater evidence of portfolio balance effects and weaker signaling reactions to U.S. UMP shocks.

The previous TMSs were not specifically modified to account for changes in debt supply. Jarrow and Li (2014) use a Heath, Jarrow, and Morton (1992) (HJM) TSM that is modified to account for bond purchases to estimate the impact of asset purchases. In this model, the observed forward interest rate is a function of both a “true” forward rate process and the price impact of Fed activities, i.e., announcements and transactions. The Fed’s price impact is a deterministic function of the forward rate’s remaining time to maturity. The evolution of the zero coupon price is therefore piecewise, differing before and after the termination of the central bank’s purchases. The Fed’s QE1 and QE2 reduced “short- to medium- term forward rates” with the impact on forward yields peaking at 6 years. The authors estimate the two programs reduced 1, 2, 5, 10 and 30 year bond yields by 327, 26, 50, 70, and 76 basis points, respectively, which are consistent with the lower range of estimates from event studies. Although QE1 and QE2 did not impact “long-term” forward rates, these are defined as 12 years or greater, which seems much too long a horizon to expect either signaling or local supply effects of 3- to 10-year bond purchases.

4.5.11 Shadow rate studies

Researchers have developed specialized TSMs to measure the stance of monetary policy when the traditional monetary policy instrument reaches the ELB. Following Black (1995), these take the form of a shadow rate TSM that respects the zero lower bound constraint on the short-term nominal interest rate. Such models characterize the short-term interest rate as the maximum of a latent 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 forward rate approximations to the shadow interest rate. Krippner (2013b) shows that the estimated U.S. shadow rate became negative in November 2008, near the first Fed QE announcement, and decreased further in August 2010, when Chairman Bernanke hinted at further asset purchases by the Fed. Moreover, it has increased since May 2013, the beginning of the “taper tantrum.” Wu and Xia (2016) estimate a factor-augmented VAR (FAVAR) that provides evidence that LSAPs
have helped lower the shadow rate. Moreover, in an event-study approach, Wu and Xia (2016) further show that the shadow rate declined during major LSAP announcements, while it increased during the taper tantrum. Bauer and Rudebusch (2016) show that shadow rate TSMs — because they are constructed to account for the ZLB — forecast future short rates more accurately than conventional TSMs.

The specification of shadow rate models is controversial, however. Krippner (2013a, 2013b) shows that shadow rate estimation is sensitive to model specification, while Claus, Claus, and Krippner (forthcoming) and Francis, Jackson Young, and Owyang (2014) argue for two-, rather than three-factor models. Shadow rate models are promising tools for modeling interest rates and assessing the effect of UMP near the ELB but they are sensitive to specification and the data used in the estimation (Krippner (2017)).

4.5.12 Emerging market effects

Lim and Mohapatra (2016) investigate the effects of Fed, ECB, BOJ and BOE QE on gross financial inflows to 60 EMs over 2000Q1–2013Q, using an unbalanced panel regression. The authors examine gross flows because of their responsiveness to monetary policy. The authors identify portfolio balance, liquidity and signaling/confidence channels and proxy for those channels with observable variables — 3-month yields, yield spreads, international short spreads and the VIX — and then estimate a “latent” effect of QE over and above the effect through those observables. The authors find significant effects from the observables representing all three channels, as well as the residual (“latent”) QE channel. The QE effects account for a modest 5 percent of gross inflows for a typical EM. The modest effects are consistent with those found by Bowman, Londono and Sapriza (2015) in their study of Fed QE effects on financial markets in emerging economies. Unsurprisingly, portfolio flows (particularly fixed income flows) are more sensitive to QE than FDI. The latter result confirms the finding of Fratzscher, Lo Duca, and Straub (2017). The authors interpret their results as indicating that G4 monetary policy spills over to EMs powerfully but in poorly-understood ways, making it difficult to mitigate destabilizing effects.

4.5.13 Dynamic announcement impact

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 on asset prices last. The persistence of such effects is potentially important because transient effects on yields or other assets will presumably produce much smaller effects on the real economy.

58 Lim and Mohapatra (2016) define their confidence channel as a combination of signaling and expectations about deflation and reduced volatility/uncertainty.
To investigate the persistence of Fed QE1 asset purchase announcements, Wright (2012) used a 1-lag structural vector autoregression (SVAR) to model the dynamic behavior of U.S. interest rates. Impulse responses from the SVAR results imply that UMP announcements have transient effects on bond yields, with half-lives of three to six months. Such brief effects would cast serious doubt on the macro efficacy of asset purchases because stimulus would be temporary.

Neely (2016) shows Wright’s (2012) SVAR fails tests of structural stability and forecasts very poorly, indicating misspecification. 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 argue that restricted models that respect plausible asset return predictability are more stable and imply that the UMP shocks were fairly persistent. Estimates of the dynamic paths of asset prices should respect the limited predictability in asset prices.

Still, there is some plausible evidence of limited “dynamic” impact of asset purchase announcements. Mamaysky (2018) investigates the dynamic responses of six types of asset prices — short and long bonds, equities prices, implied equity volatility and CDS rates — to UMP announcements from the Fed, the ECB and the BOE. The author argues that rational inattention might delay full equity responses to UMP announcements. He investigates this possibility by bootstrapping paths asset price paths from a data generating process with no delayed effects to see if the observed dynamic responses are unusual compared to the null. The “most unusual” reactions to QE announcements come at very short horizons for bonds but at much longer horizons of three weeks or more for equities. Bootstrapping indicates that these are very likely delayed responses to the monetary announcement rather than random movements. Confirming this interpretation are the facts that bond prices appear to anticipate monetary announcements over a span of weeks but equity markets appear to react in a delayed fashion. Finally, the fact that stocks with high bond betas (more bond-like stocks) react more quickly to QE announcements than stocks with low bond betas appears to support Mamaysky’s (2018) conclusions.

There are at least two important differences between Mamaysky’s (2018) study and most other dynamic impact studies: Mamaysky (2018) limited the search for dynamic impacts to a span of a few weeks and the size of the maximal impact was estimated with a bootstrapping procedure that accounted for the length of the search horizon.

4.5.14 Deficits, the maturity of the U.S. debt and yields

The work of Wright (2012) indicates that it was a statistical regularity that U.S. yields tended to rise in the months after QE announcements had lowered them. One interpretation of this regularity is that markets consistently initially overreacted to such shocks. Another interpretation is that QE-related declines in yields were consistently followed by endogenous responses that partly or even completely offset them. One candidate for such endogenous responses was that
UMP announcements improved confidence that gradually increased investment that raised yields. A second candidate was an endogenous change in the maturity structure of the U.S. debt.

As the Fed’s UMP reduced long yields after the financial crisis, the U.S. Treasury responded by lengthening the maturity of U.S. Treasury debt to reduce financing costs and the risks associated with short-term debt.\(^{59}\) Greenwood et al. (2014) argue that this change in the maturity structure was a significant factor in the low-frequency behavior of long yields in the wake of the crisis.\(^{60}\) These authors estimate the Treasury’s maturity extensions raised the yield on 10-year Treasuries by about 45 b.p., or about 1/3 of the cumulative impact of the Fed’s QE policies, as estimated by other studies. These authors further argue that, while the Treasury should manage the maturity of Treasury debt in normal times, more coordination is needed during UMP regimes. The problem of the Fed and Treasury working at cross purposes was novel during the 2009-2014 period because, prior to 2009, Fed long bond holdings were relatively small and so did not conflict with Treasury debt priorities.

### 4.5.15 Quantity of debt regression studies

Researchers have used lower frequency regression studies to complement or substitute for ubiquitous event study evidence. Broadening research procedures allows researchers to check the robustness of event study conclusions with other methods.

The second part of Gagnon et al. (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. The regressors include net government bond supply with at least a year to maturity — net of Fed and foreign official holdings of Treasury, agency and corporate securities with at least a year to maturity — and macro control variables \((X_{t})\). The term premium regression can be written as follows:

\[
TP_{t}^{KW} = a + b \times \text{bond supply}_{t} + c \times X_{t} + e_{t}
\]  

(47)

All regressors are highly statistically significant. The authors conclude that the Fed’s asset purchases lowered long-term private borrowing rates which should stimulate economic activity. The regression implies that QE1 decreased the term premium by 52 basis points and the 10-year Treasury yield by 82 basis points.

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 et al. (2011). The authors regress long corporate-Treasury yield spreads on the maturity structure of

---

\(^{59}\) The U.S. government also ran large deficits during and long after the financial crisis. The increased debt could also raise long yields through adding duration risk, local supply and increasing inflation risk.

\(^{60}\) This discussion would echo the observation of McCauley and Ueda (2009) that the BOJ had actually reduced the maturity of its own portfolio in 2001-2005.
government debt-to-GDP along with controls for volatility and the slope of the yield curve with annual data, 1949 to 2008. Concerns about the endogeneity of the debt structure prompt the authors to 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.

Chadha, Turner, and Zampolli (2013) also use low frequency data to study how the maturity structure of debt in the hands of the (non-central bank) public affects yields. To do so, the authors extend the empirical work of Laubach (2009) — who had previously estimated the effect of the quantity of Federal debt on yields — to also account for the maturity of Federal debt. Using data from 1976 to 2012, Chadha, Turner, and Zampolli (2013) estimate that reducing the average maturity of U.S. Treasury debt held outside the Fed by one year would decrease the five-year forward and 10-year yield by between 130 and 150 basis points, which is consistent with a large portfolio balance effect.\(^61\)

Thornton (2014) takes issue with the regressions run by Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011) and Greenwood and Vayanos (2014). After first criticizing the construction of debt statistics, Thornton (2014) replicates the reduced-form regression results of Gagnon et al. (2011) and then argues that the inference is not robust to inclusion of a time trend in the model. Including the time trend — which is statistically significant — generally reduces the size and eliminates the statistical significance of coefficients describing the effect of changes in debt quantities on yields/term premia.\(^62\) Thornton (2014) concludes by arguing that there is no evidence from this sort of exercise that the Fed’s asset purchases reduced yields. This is a convincing critique of these specific regression methods in these papers.

Regression studies of the effect of debt supplies on yields have a number of potential problems. 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, which creates non-standard distributions of the coefficient estimates, as well as 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 valid in principle but that

---

\(^{61}\) Although some authors warn that similar coefficients may be biased downwards, underestimating the portfolio balance effect, Chadha, Turner, and Zampolli (2013) warn that the portfolio-balance effect estimates may be biased upwards to the extent that the Treasury manages its maturity structure to reflect expectations about yields.

\(^{62}\) 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 (2012c) and others. For example, Chen, Curdia, and Ferrero (2012) produce a portfolio-balance effect from participation constraints, building on preferred habitat theory.
one obtains a negative result — that bond supplies have no effect on yields — if one treats trends “properly.” Because it is not clear why a trend should belong in such a regression, a significant coefficient on a time trend might indicate misspecification.

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 variation in the level of government debt is probably often fairly predictable. For example, the fact that U.S. government debt would increase substantially from the tax cuts and defense buildup of the 1980s was obvious many quarters, if not years, before the bonds were actually issued. That means that yields should have changed long before quantities changed. The forward looking nature of bond markets is a fundamental problem with low-frequency studies of financial variables.

To cope with this problem, Wu (2014) constructs forward-looking market projections of the magnitude and duration of the Federal Reserve's Large Scale Asset Purchases (LSAP) program. He uses those data in a regression model, which also incorporates macro and financial variables, to estimate that Fed asset purchases have lowered the 10-year term premium by 100 b.p.

4.5.16 Regression studies of the MBS purchase programs

A pair of papers, by Hancock and Passmore (2011) and Stroebel and Taylor (2012), came to diametrically opposed conclusions as to the success of the Fed’s MBS purchase program.

After describing the mortgage/MBS market, Hancock and Passmore (2011) use a narrative approach to argue that announcement of the Fed’s MBS purchase program reduced MBS yields and the mortgage-Treasury spread substantially. 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. Regressions of mortgage rates on MBS yields and house prices indicate that the Fed’s interventions brought down mortgage rates by about 100 b.p.

Stroebel and Taylor (2012) also examine the effect of the MBS purchase program on the option-adjusted spread (OAS), which is the MBS yield less LIBOR, adjusted for prepayment risk, using weekly data between 2007 and June 2010. The OAS spread compensates for MBS duration and the default risk. The authors regressed many OAS measures on controls for default risk and numerous Fed MBS purchase variables, including cumulative MBS purchases, dummies for first purchase dates, and the March 2009 expansion announcement. Many but not all of the coefficients on QE programs are wrongly signed (positive) or insignificant, which the authors interpret as indicating that Fed MBS purchases did not affect the OAS. But some specifications show a substantial effect of the purchases. The persistence in and correlation among regressors produces some unexpected results. For example, cumulative QE purchases, which is a very persistent regressor, often has a statistically significant, perverse sign, which the authors curiously interpret as canceling out evidence from other specifications that support MBS
purchase effectiveness. The authors ultimately attribute the declines in mortgage rates to lower prepayment and default risk.

How can one reconcile Hancock and Passmore’s (2011) positive assessment of the MBS program with Stroebel and Taylor’s (2012) equally negative assessment?

First, one should note that the two studies focused on different variables. While Hancock and Passmore (2011) decomposed mortgage rates into a mortgage-MBS spread and an MBS-swap spread, Stroebel and Taylor (2012) focused on a narrower variable: the OAS spread. MBS yields are determined by expected future short-rates and premia for prepayment, default and duration risk. By using the OAS spread in regressions with controls for default risk, duration risk is the only significant component left for QE to explain. “Little remains to be explained by MBS purchases” (Stroebel and Taylor (2012), page 20).

Second, event study evidence appears to be consistent with the hypothesis that the MBS purchase program lowered MBS yields and mortgage rates. Table 1 in Gagnon et al. (2011) — from 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. That is, the unadjusted MBS-swap spread declined by 15 and -8 basis points on those two dates.

4.5.17 Regression analysis of corporate credit risk

Gilchrist and Zakrajsek (2013) study the effects of the Fed’s UMP events (2008-2011) on market-based indicators of corporate credit risk, that is, credit derivative indices, using both an event study and a system of equations using daily data where policy shocks are identified by their higher variance on known announcement dates (Rigobon and Sack 2003, 2004). The regression system identifies causal inference in the presence of simultaneity, that is, where interest rates and CDS rates may respond endogenously to shocks about economic growth and/or risk premia. UMP announcements may have been accompanied by such shocks, potentially contaminating the inference from event studies. Consistent with the Krishnamurthy and Vissing-Jorgensen (2011) event-study, the Gilchrist and Zakrajsek (2013) system shows that Fed QE1 announcements broadly reduced default risk for both investment grade and speculative grade bonds. But the authors find no evidence that the announcements decreased default risk in the financial sector. This is potentially inconsistent with the findings of Hattori, Schrimpf and Sushko (2016), who found that UMP announcements reduced option-implied equity tail risk.

4.5.18 Segmented markets analysis

Hamilton and Wu (2012) use a calibrated, discrete-time Vayanos and Vila (2009) framework to study how the maturity of government debt affects the term structure of interest rates using yield and debt data from 1990 to 2007. Their specific debt measures are the average maturity of public debt and the percent of public debt with maturities longer than 10 years. The authors 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 consistent with the lower end of event study estimates of 40 - 100 b.p. declines in the 10-year Treasury yield for the $1.725 trillion QE1 purchases.

Also building on Vayanos and Vila’s (2009) segmented-markets model, Greenwood and Vayanos (2014) use a TSM to motivate and inform the predictions of a regression model of yields on two measures of U.S. government debt supply: maturity-weighted debt to GDP, and long-term-debt-to-U.S.-GDP, over two subsamples, 1952 to 2007 and 1916–1940. Because debt maturity structure is endogenous to the shape of the yield curve, the authors instrument maturity-weighted debt to GDP with marketable U.S. Treasury debt-to-GDP. They find maturity-weighted debt-to-GDP increases long yields; the Fed’s QE1 and QE2 together reduced yields by 40 basis points, which is smaller than 70 - 110 b.p. range implied by the event-studies of Gagnon et al. (2011), D’Amico et al. (2012), and Li and Wei (2013), but still sizable.

Ihrig et al (2018) attempt to remedy two failings of most of the literature: 1) Traditional event studies can only gauge program effects at announcement time and 2) it is very difficult to compute the impact of changes in forward-looking expectations of quantities. Using TSM methods based on Vayanos and Vila (2009) and Li and Wei (2013), Ihrig et al (2018) estimate the effect of Fed asset purchases on term premia. The TSM has two yield curve factors and three supply factors that drive yields. The authors impose that bond supply factors evolve in a manner consistent with market expectations of private bond holdings, which were constructed with the methods of Carpenter et al. (2015). The potential strength of the methods is that they can estimate the effect of an announcement on yields at an arbitrary point in time, using the pre/post announcement difference in the implied paths for the term premium. This allows them to estimate the dynamic effect of a program. On the other hand, as the authors acknowledge, the methods do rely on assumptions about the evolution of market expectations. The authors assess the effect of 7 Fed supply events (4 program announcements, 2 reinvestment announcements and a program extension). The authors estimate that, as of 2015Q1, all Fed QE operations together had reduced the 10-year term premium by 100 b.p. with a 90 percent confidence range from about 55 to 145 b.p..

4.6 Fed and BOE support for bank lending

Asset purchases can influence bank lending through several channels: increasing the supply of reserves, reducing funding costs to zero, and/or raising bank capital ratios by boosting the prices of bank assets. Rodnyansky and Darmouni (2017); Kurtzman, Luck, and Zimmermann (forthcoming); and Chakraborty, Goldstein, and MacKinlay (2017) write related papers that examine how the Fed’s choice of assets to purchase affects the quantity, types and risk characteristics, respectively, of the cross section of bank lending. All three papers study how a
bank’s MBS holdings affects its response to QE1 and QE3—both of which featured MBS purchases—and use QE2, which only purchased Treasuries, as a control period.  

Rodnyansky and Darmouni (2017) construct matched groups with the 25% lowest/highest MBS-to-asset ratios and then regress lending variables on QE dummies interacted with controls and the MBS treatment indicator. Institutions with relatively larger holdings of MBS expanded lending after QE1 and QE3, but not after QE2. Curiously, the authors also find that QE1 worked by increasing the net worth of banks while QE3 worked by increasing liquidity. The investigation was purely cross-sectional, permitting no inference about aggregate effects.

Using a difference-in-differences design and data from the Fed Board’s Senior Loan Officer Opinion Survey on Bank Lending Practices (SLOOS) and the Survey of Terms of Business Lending (STBL), Kurtzman, Luck, and Zimmermann (forthcoming) show that banks with greater MBS holdings reduced lending standards and made riskier loans. The effects were primarily on real estate loans during QE1 and C&I loans in QE3. Higher capital ratios produced the QE1 effect. Each round of asset purchases had a quantitative impact comparable to a one percentage point decrease in the Fed funds target.

Banks potentially benefit from Fed MBS purchases through both capital gains and by originating and securitizing mortgages to meet the MBS purchase requirements. Chakraborty, Goldstein, and MacKinlay (2017) use four sets of micro data on individual banks and/or firms from 2005Q4 through 2013Q4 to show that Fed MBS purchases increased mortgage lending relatively more in banks with greater MBS holdings but this effect crowded out Commercial & Industrial (C&I) lending. Rodnyansky and Darmouni (2017) did not find such crowding out, a fact that Chakraborty, Goldstein, and MacKinlay (2017) attribute Rodnyansky and Darmouni’s (2017) use of timing alone to identify changes in bank behavior, which conflates the effect of QE with other policy changes. Firms associated with these high-MBS exposed banks reduced their investment following QE1 and QE3. The authors conclude by arguing that QE designs should consider the type of asset purchased.

In summary, the effect of Fed asset purchases on bank lending depended on the type of bond purchased. MBS purchases had heterogeneous lending effects across depository institutions, rather than “raising the tide and lifting all boats.” Institutions that owned greater amounts of MBS increased mortgage lending more but also reduced lending standards. Increased mortgage lending appears to have crowded out C&I lending.

In the U.K., the MPC did not expect that its long-maturity bond purchases would work through a bank lending channel. Such asset purchases did increase liquidity, bank reserves and

---

63 Banks hold few Treasury securities so purchases of Treasuries should not necessarily affect banks differently.
64 The authors explain that because the Federal Reserve purchases MBS through the to-be-announced (TBA) market that focuses on new mortgages, banks have a strong incentive to originate and securitize new mortgages to fulfill specified contracts in that market.
deposits, however, which might make banks more willing to lend. Joyce and Spaltro (2014) use a confidential panel data set of 30 U.K. banks from 1989Q2 to 2010Q4 with reduced form regressions to investigate how the BOE’s initial (2009-2010) asset purchases affected bank lending. The authors use pre-crisis regression estimates to calculate the baseline effect of BOE QE on lending in 2009-2010.\(^{65}\) The estimated effects implied a very modest banking channel: Small but greater for banks that were small and/or better capitalized and/or with less access to external funding. This is another example indicating that well capitalized banks better transmit monetary policy.

Butt et al. (2015) also investigate a bank lending channel with a unique monthly, confidential BOE dataset that combines balance sheet, regulatory and market operations data for individual banking groups. A perennial problem in investigating the impact of monetary policy on bank lending is to separately identify the causal effect of changes in deposits on lending from the reverse. To accomplish this, the authors use monthly gilt purchases from each bank’s customers as an instrument for deposits in regressions. The authors find no evidence for a bank lending channel in the UK. That is, banks that received QE deposits failed to expand lending more than those that did not.

The BOE FLS scheme provided incentives for U.K. banks to lend to domestic firms. These incentives could distort lending away from international clients. Forbes, Reinhardt, and Wieladek (2017) use a “unique U.K. dataset” to explore the role of regulatory and unconventional monetary policy in two large, post-crisis contractions in international lending, in 2008-2009 and 2011-2012. The authors find that the combination of increases in microprudential capital requirements and the FLS magnified the contraction in cross-border lending, reducing U.K. lending by 30 percent and international lending by 10 percent. Preexisting, strong microprudential capital requirements insulated countries from the contraction. The BOE’s asset purchases did not affect the contraction. This contraction illustrates unintended consequences: A policy to boost domestic lending (the FLS) can reduce international lending.

Research provides little evidence that BOE asset purchases sparked much additional bank lending, although the BOE did not expect it to do so. There is intriguing evidence of a presumably unintentional distortion, however: the FLS appears to have skewed lending from international destinations to domestic customers.

4.7 **Fed remittances to the Treasury**

By 2012, after years of asset purchases, the Fed’s balance sheet was very heavy in long-dated assets. Analysts became concerned about the Fed’s exposure to balance sheet or income losses

\(^{65}\) The Chow test fails to reject the null of coefficient stability during the crisis but the variance also changes so the test is not strictly applicable.
should interest rates generally rise (Hall and Reis (2013)). As Christensen, Lopez, and Rudebusch (2015) point out, although profits and losses are distinctly secondary concerns for central banks because they can always print money or issue reserves, the issue is still disquieting because capital losses or negative income could draw political scrutiny and erode a central bank’s independence. Christensen, Lopez, and Rudebusch (2015) build on the work of Carpenter et al. (2013) and Greenlaw et al. (2013) to quantify the likelihood of balance sheet or income losses for the Fed. Using a shadow-rate, arbitrage-free Nelson-Siegel (AFNS) model class developed by Christensen and Rudebusch (2015) to model and simulate interest rate movements, the authors calculate that the Fed’s remittances to the U.S. Treasury — income less costs — remain positive up to seven years ahead, in more than 90% of the simulated scenarios.

4.8 Forward guidance

Forward guidance is central bank communication about future monetary policy. It has been used both in periods of conventional and unconventional policy. A primary question in discussing forward guidance is whether it is Delphic or Odyssean, that is, whether it predicts future economic conditions or attempts to commit to a future course of action (Campbell et al. 2012). Of course, it could be used in either or both ways, depending on the circumstances.

Raskin (2013) investigated the impact of early Fed forward guidance by measuring changes in option-implied, risk-neutral distributions for short-term interest rates. He concluded that the Fed’s early date-based guidance seemed to be Odyssean. Guidance effects varied over time, however, with the FOMC’s promise to keep rates low until “mid-2013” having a much bigger effect than the same promise to keep rates low until “mid-2014.” Such variation may be expected, however, as the economic circumstances were different between the two periods.

In contrast to Raskin’s (2013) interpretation of Fed guidance events to be Odyssean, the New York Fed Surveys of primary dealers indicate that these market participants see important Delphic information in forward guidance, including information about employment (Femia, Friedman, and Sack 2014). Again, this may not indicate a contradiction as guidance can be both Odyssean and Delphic, even in the same announcement.

Altavilla and Giannone (2015) ask how Fed forward guidance affected expectations derived from the Survey of Professional Forecasters. After controlling for other variables within a

---

66 Balance sheet losses are the loss in market value of Fed’s portfolio as interest rates rise. Income losses would occur if the Fed’s interest payments to banks for reserve deposits would outpace the coupon and interest income the Fed receives from its securities.

67 The term “Delphic” comes from the ancient Greek Oracle of Delphi, who was a priestess who delivered messages from Apollo, including predictions of the future. “Odyssean” derives from the name of the Greek hero, Odysseus, who committed himself to action by having the crew of his ship tie him to the mast so that he could not jump to his death when hearing the song of the Sirens, mermaids with beautiful voices who lured sailors to watery deaths.
quarter, the authors find that UMP affects yields in a manner similar to that found in event studies. Further, the Survey of Professional Forecasters expects UMP-induced yield changes to persist in contrast to the econometric work that suggests they are transient. The results in Altavilla and Giannone (2015) broadly support event study methods in that the UMP effects on SPF forecasts are consistent with those estimated by event studies.

Working off the assumption that effective forward guidance should improve interest rates forecasts, Kool and Thornton (2015) find weak evidence that forward guidance improves Consensus Economics 3-month and 10-year interest rate forecasts for New Zealand, Norway and Sweden, but not the United States. To test their hypothesis, the authors essentially compare average squared forecast errors before and after the adoption of forward guidance. The authors interpret the lack of consistent statistical significance across countries and specifications as indicating that forward guidance is not effective. We believe, however, that this interpretation is strained. The evidence was mixed over countries, benchmarks and horizons.

There are significant problems with such tests. For example, such tests are likely to have limited power on such short samples. Further, interest rate predictability/volatility may differ across samples and more volatile regimes may prompt the introduction of forward guidance. Finally, the possibility exists that, in finite samples, central bank guidance moves markets in the desired direction but this guidance turns out to be insufficient to produce good forecasts. To illustrate the latter two points, Figure 9 depicts the federal funds rate from 2008-2018 with implicit “forecasts” from federal funds futures. First, the market seems to have been systematically wrong in that futures prices badly overpredicted the fed funds rate for 8 or 9 years. In other words, it was a difficult period to predict interest rates. Periods when UMP is used are likely to exhibit unusually high uncertainty. Second, listening to expansionary Fed guidance in 2008-2013 would have reduced those errors considerably.

One of the most difficult problems in studying UMP is to separately identify the effects of policies whose announcements occur simultaneously. Using data from 1995-2015, Swanson (2017) uses a 3-factor model to disentangle the separate effects of conventional policy, forward guidance, and asset purchase announcements. After estimating the factor model, Swanson (2017) searched for a rotation of the factors that would match the impact of “target,” “path” and unconventional shocks. The assumptions were that forward guidance would affect short and medium rate while unconventional shocks should affect long yields and interest rate uncertainty. Swanson used 2 specific identification schemes, which each produced similar inference. The results implied that forward guidance has short term effects, lasting 1-4 months, while conventional monetary policy has persistent effects.

68 Previously, Gürkaynak, Sack and Swanson (2005) had pioneered the use of 2-factor models to model the impact of conventional “target” and “path” shocks.
It is difficult to generalize about the effect of forward guidance for a number of reasons. It has often been used with announcements of other policies, such as asset purchases, making the separate effects difficult to disentangle. Central banks can use forward guidance to convey a wide variety of information, from Delphic to Odyssean, and different types of information might be more or less credible to markets. In addition, the particular circumstances in which central banks employ guidance seem to be crucial in its impact.

4.9 ECB support for bank lending

Given the importance of banks in the euro area, the ECB acted early in the financial crisis to support its banks, including providing liquidity elastically (FRFA) and purchasing covered bonds to provide funding (CBPP). In 2014, the ECB Governing Board followed those support measures by creating a conditional credit program known as Targeted Longer-term Refinancing Operations (TLTROs) to provide credit to banks and incentives to lend.

A series of papers examined how bank characteristics — e.g., bank location, capital ratio, and exposure to sovereign debt — affect the transmission of various types of monetary policies, from bank lending programs to asset purchases. The literature finds mostly positive outcomes: UMP reduced deposit rates, borrowing costs and spreads but the effects do depend on bank characteristics. In particular, bank riskiness (capitalization) matters for monetary transmission. The literature also finds that policies tend to spill over from the market it directly effects to other markets.

To study how the FRFA influenced bank deposit and loan spreads both before and after the financial crisis, Achary, Imbierowicz, Steffen, and Teichmann (2017) construct their own data set of bank deposit and loan spreads for European banks and firms from January 2006 through June 2010. Prior to the FRFA policy, increases in liquidity reduced deposit rates of low risk banks but had no effect on those of other banks or on any loan spreads. The introduction of FRFA in October 2008 reduced deposit rates for both high and low risk banks but not lending spreads for high risk banks. The authors argue that the medium and long term loan mechanisms were impaired because aggregate liquidity didn’t change long-term loan spreads of either high or low risk banks and it decreased medium-term spreads only for low risk banks. This suggests that the good capital condition of banks is a precondition for effective monetary policy.

Szczerbowicz (2015) uses event study regressions to characterize how the ECB’s liquidity policies — i.e., 3-year LTROs, a 0 percent ECB deposit rate, FRFA, the SMP, the OMT announcement and CBPP1 and CBPP2 — influenced borrowing costs of banks and governments. The exceptional liquidity measures significantly reduced money market tensions but the asset purchases most effectively lowered covered bond borrowing costs for banks and sovereign yields for governments, especially those of high-risk countries. Asset purchase effects spilled across markets. Covered bond purchases reduced sovereign yields and the SMP/OMT reduced covered spreads even more than the covered bond purchases.
Bank lending programs can lower sovereign borrowing costs by subsidizing a bank carry trade in which the banks borrow from the central bank to buy government assets. Crosignani, Faria-e-Castro, and Fonseca (2017) use micro data to show that Portuguese banks borrowed from the Three-year LTRO program to buy government securities and then used those securities as collateral to borrow more reserves, matching the maturities of the bonds and loans to avoid risk. Such purchases drive down short-term peripheral yields. Banks in other peripheral countries, like Italy and Spain, followed the same strategy but banks in the core did not. The authors assert that they show that long-term lending induces banks to buy high-yield collateral assets.

One might expect that bank characteristics influence how monetary policy transmits through banks and affects them. Altavilla, Canova, and Ciccarelli (2016) investigate pass-through of euro area monetary policy — conventional, TLRTOs and APPs — to firm and household borrowing rates using a novel, monthly, bank-level data set spanning 2007-2015. Bank location (periphery vs. center) did not affect pass-through of conventional policy once one accounts for bank capital ratio, exposure to sovereign debt, and the ratio of non-performing loans. TLRTOs and APPs helped to normalize lending conditions, to increase lending to households, to reduce the cross-sectional dispersion of lending rates and to raise pass-through. These programs were particularly helpful to banks with low capital ratios and high ratios of non-performing loans. Disturbingly, however, non-standard monetary measures may have made banks more vulnerable to shocks by compressing their borrowing-lending spreads and thereby reducing profits.

UMP also unintentionally encouraged zombie lending, according to Acharya, Eisert, Eufinger, and Hirsch (2017). The SMP/OMT programs supported euro-area banks by raising the prices of the periphery-area bonds held by those banks and thus raising the banks’ capital. The ECB expected the OMT to increase loan supply by strengthening bank balance sheets but Acharya, Eisert, Eufinger, and Hirsch (2017) argue that the OMT insufficiently recapitalized banks, which created incentives to avoid admitting losses but allowed marginal banks to extend loans to failing firms (zombies) at below-market rates. Effects were heterogeneous. Poorly (well) capitalized banks increased (reduced) their zombie lending. Non-zombie firms used increased credit to build cash reserves; zombies used their loans to pay interest on debt. Further, the loans to zombie firms had negative knock on effects. That is, credit-worthy firms in sectors with lots of zombies suffered, presumably because zombie firms competed for both specialized workers and customers. There was no change in real activity for either zombies or non-zombies. The authors conclude that a well-capitalized banking sector is important for transmission of monetary policy and that the ECB should have directly recapitalized banks.

Liquidity provision requires well-capitalized banks. Asset purchases may be more effective than direct lending to banks. Bank lending support programs can indirectly subsidize sovereign borrowing costs.
4.10 ECB asset purchases: CBPP, SMP/OMT, and APP

The ECB used narrow asset purchase programs to support bank funding (CBPP, ABSPP), sovereign bond markets (the SMP/OMT) and corporate borrowing (CSPP). In 2015, the ECB also created a much larger program to broadly stimulate the economy (the PSPP). This subsection reviews the literatures on those programs.

4.10.1 The ECB CBPP

The goal of the CBPP iterations were to provide external funding for banks. By providing a steady purchaser of covered bonds, the ECB hoped to reinvigorate and implicitly subsidize the market for issuers. Beirne et al. (2011) use two types of event studies and a regression study to examine the behavior of the 5-year covered bonds swap spread, i.e., the 5-year covered bond yield less the 5-year swap rate. Studying the covered swap spread isolates covered yields from overall movements in the yield curve. Regressions imply that the CBPP reduced covered bond swap spreads by 12 basis points, encouraged lending, improved liquidity and induced substitution from uncovered issuance to covered issuance. The CBPP even broadened the covered bond market, encouraging euro area institutions, particularly in smaller markets, to begin using it for funding.69

4.10.2 The ECB SMP and OMT

The SMP and OMT programs were conducted for limited purposes, to repair market functioning that impeded monetary transmission, not to provide general stimulus. The intermediate goal of the SMP/OMT literature was to characterize the effect of those programs on yields and market functioning and infer the channels through which those effects occurred. Confidential daily data on SMP purchases was available to ECB researchers but data for the public was only available at weekly frequency. The ultimate goal of this line of research was to come to a judgment on the overall effect of these programs on the crisis.

A key issue in the study of the ECB’s SMP program is that the ECB purchased securities as-needed in response to market conditions. The fact that neither the program’s size nor pace were announced in advance means that most the impact of the program probably occurred as markets learned about the ECB reaction function from transactions. If SMP transactions responded to liquidity and default conditions that were systematically associated with changes in yields, any evaluation of SMP effects must confront significant simultaneity/endogeneity problems to avoid confusing conditions that cause SMP purchases from the effects of those purchases.

Three major papers on the programs used differing identification assumptions and estimation strategies to study the effect of SMP purchases. To overcome the simultaneity problem, Eser and

---

69 Neely thanks Magdalena Grothe for personal communications regarding an anomalous result in their paper.
Schwaab (2016) argue that coordination within the large Eurosystem required the purchase decisions and amounts to be predetermined at a daily frequency. These authors employ a 2-factor model of ten euro area yield curves and purchases of the debt of specific countries. Taking issue with the predetermination assumption, both Ghysels et al. (2016) and Fratzscher, Lo Duca, and Straub (2016) argue that simultaneity/endogeneity problems exist at the daily (or lower) frequency. Using confidential SMP transactions data, Ghysels et al. (2016) illustrate such problems by contrasting insignificant daily VAR results with significant results from high-frequency intraday data. To deal with simultaneity/endogeneity and still use publicly available weekly data, Fratzscher, Lo Duca, and Straub (2016) create a reaction function for weekly SMP purchases and use the unexpected component of such purchases in event study regressions. A series of personal communications with the authors of these papers — one author from each set — suggests that the identification issue turns on how frequent and important the endogenous intraday variation is.

Using confidential daily transactions data from the ECB, October 1, 2008 to December 20, 2011, Eser and Schwaab (2016) investigate how SMP transactions affected yields and volatility with a panel regression of yields explained by control variables, such as U.S. yields and the VIX, factors from a 2-factor model of ten euro area yield curves and purchases of the debt of specific countries. On both important SMP announcement days, May 10, 2010 and August 11, 2011, yields in smaller and more stressed markets declined more than those in larger markets and the short end of the curves declined more than the long ends. The smaller impact on long yields may reflect expectations of temporary impacts as a dynamic specification implies some reversion of yield effects, which the authors interpret as being consistent with dealer inventory effects. Controlling for bond market sizes, the SMP reduced yields by 3 b.p. per 1/1000 of debt purchased. Finally, SMP purchases were associated with lower volatility, kurtosis and tail risk.

Eser and Schwaab (2016) credit the yield declines to reductions in liquidity risk and default risk, as well as some signaling effects. These authors argue that SMP transactions conveyed the ECB’s evaluation of the level of a country’s yields, rather than sending signals about monetary

The second author (Neely) thanks Bern Schwaab, Marco Lo Duca, and Olivier Vergote for generous personal communications on the understanding of each set of authors on ECB SMP purchase procedures. Bernd Schwaab states that daily purchase amounts were discussed and agreed upon in a teleconference before markets opened in order to coordinate purchases. Amounts were adjusted within the day only rarely. The Eser and Schwaab factor setup was useful to control for conditions in troubled markets. Marco Lo Duca states that the ECB decided a daily SMP purchase amount by observing market conditions during initial trading. Once the ECB decided the total size of a day’s purchases, the need for coordination within the Eurozone permitted little or no room to adjust the total further within the day. Olivier Vergote argues that purchasing managers had some flexibility about how to allocate purchases, whether to spend the full amount or ask for additional funds. The common factor driving the intensity of the purchases was the intensity of the sovereign crisis. Vergote suggests that one interpretation of the results is that “Eser and Schwaab account for the common factor by using a panel regression with common latent factors” while Ghysels et al. (2016) use intraday data to overcome the simultaneity at daily frequencies. Vergote notes that the consistency of results between the two methods should be comforting.
policy. Despite the success in reducing yields and volatility, Eser and Schwaab (2016) conclude that the SMP was not sufficient to end the euro debt crisis.

Ghysels et al. (2016) apply VARs to confidential SMP transactions data and high frequency price data to examine SMP effects on sovereign yields of several euro area countries, including Spain, Italy, Portugal, Greece, and Ireland, from January 2011 to March 2012. The paper contrasts daily results with high-frequency intraday data to illustrate simultaneity/endogeneity problems. SMP transactions never have a significant impact with daily data but they have substantial effects on yields in almost all markets with high-frequency data and these effects generally take their long-run value within an hour or so. SMP purchases also reduced the conditional volatility of yields implied by a multivariate GARCH model fit to the VAR residuals.

The ECB may have devised a strategy with some unpredictability to avoid strategic gaming by market participants because Ghysels et al. (2016) find that the SMP reaction function is not well defined. The authors conclude that SMP purchases have successfully reduced yields for every country but Greece. The Greek exception underscores the need for fundamental fiscal sustainability.

Fratzscher, Lo Duca, and Straub (2016) use a panel event study regression for key announcements with daily data from 38 countries, from May 1, 2007 to September 30, 2012, to characterize the impact of OMTs, SMPs and SLTROs on international portfolio flows and a variety of international asset prices. Core, periphery and emerging euro area countries are grouped separately, as are advanced and emerging non-EU economies. The authors include many macro surprises as control variables. All three types of policies — LTROs, SMP and OMT — lowered euro periphery bond yields but had no effect on non-EMU yields, in contrast to the strong effect of Fed asset purchase programs on international yields (i.e., Neely (2015)). The ECB OMTs, SMPs and SLTROs had little impact on international portfolio flows, which contrasted with the strong effects of Fed UMP on capital flows found by Fratzscher, Lo Duca, and Straub (2017). The authors conjecture that the global importance of the dollar or the post-crisis shrinkage in the relative importance of banking vs. bonds might explain this disparity.

The SMP and OMT policies — particularly announcements — raised equity prices in both the core and periphery of the euro area. These measures also reduced implied volatility for equities and measures of sovereign risk and (mostly) modestly depreciated the EUR. The authors interpret the effects on asset prices as being consistent with increased confidence or decreased risk aversion.

Fratzscher, Lo Duca, and Straub (2016) carefully remain agnostic as to whether the SMP was an effective tool. “It is important to point out that, while we find that the SMP purchases decreased yields and boosted equity prices on impact, the paper is mute on whether the SMP was overall an effective crisis management tool.” (Fratzscher, Lo Duca, and Straub 2016, p. 57)
While previous papers investigate the SMP channels to some extent, the primary contribution of Krishnamurthy, Nagel, and Vissing-Jørgensen (2017) is to carefully investigate the channels by which SMP, the OMT and LTROs affect interest rates through an event study with a limited set of announcement events, 3 OMT events, 2 SMP events, and 2 LTRO events. Applying a Kalman filter to reduce measurement error, the authors decompose policy effects into two euro area and three country-specific quantities. Euro-area effects consist of changes to expected short rates and euro term premia while the country-specific effects consist of default risk, redenomination risk and market segmentation. The authors identify differences in country specific default vs. redenomination risk by using the facts that domestic law cannot redenominate (corporate) bonds denominated in U.S. dollars and issued under foreign law and any redenomination of domestic bonds should affect all securities issued under domestic law.

The SMP and OMT reduced yields much more than LTROs. Except for those of Spain, which had particular banking problems, LTROs had only small effects on sovereign yields. Default and redenomination risk were the most important SMP/OMT channels for reducing Italian, Spanish and Portuguese yields. Reduced default risk accounted for 37% of fall in yields. Reduced redenomination risk accounted for 13% of fall in yields while lessened market segmentation accounts for 50% of decline in yields. Krishnamurthy, Nagel, and Vissing-Jørgensen (2017) cite positive stock returns around policy events as indicating that SMP and OMT had positive economic spillovers, instead of simply being transfers from the core to the periphery.

A perennial problem with policy interventions is unintended consequences, including the creation of moral hazard. In the case of SMP/OMT, ECB programs to reduce sovereign yields might temp euro area governments to issue more debt. Jäger and Grigoriadis (2017) use pooled OLS to study whether the ECB UMP policies (OMT, SMP, LTROs, CBPP1, CBPP2, and deposit rate reductions) reduce euro-area bond spreads over the euro swap rate and prompt governments to issue more debt. Results vary by programs and group of countries: LTROs and deposit rate reductions mostly affect the spreads of non-crisis countries, which have more developed financial sectors that may benefit more from liquidity injections. The SMP lowers the spreads of crisis countries, but raises spreads in non-crisis countries. The authors reasonably conjecture that SMP purchases transfer risk from crisis to non-crisis countries, thereby providing an incentive for member states to issue more risky assets. As hypothesized, the authors find that UMP that reduces bond spreads also raises short-term government debt. In contrast, Jäger and Grigoriadis (2017) argue that the OMT reduces spreads for both crisis and non-crisis countries because it has not transferred risk.

Identification is an important issue in the study of SMP purchases. Different estimation methods — factor models, high frequency data, and reaction functions — have been proposed to consistently measure the effect of such purchases. The SMP purchases reduced short yields more than long yields and yields of stressed countries more than those of unstressed countries. They have also reduced volatility. The purchases seem to have worked mainly through country-
specific channels, such as reduce market segmentation and default risk. While the SMP has transferred risk from stressed countries to unstressed countries, the OMT has not. Interestingly, reductions in sovereign yields predicted increased debt issue.

4.10.3 The ECB APP

In January 2015, the ECB announced an open-ended asset purchase program of €60 billion euros of public and private securities, to be conducted until September 2016 and until the ECB Governing Council projects that inflation will stabilize near but below 2 percent. Altavilla, Carboni, and Motto (2016) assess the effectiveness and transmission channels of this ECB APP announcement with a TSM that includes bond supply effects. In a novel procedure, the authors validate their event set selection by examining the intensity of news coverage during the events and control for macroeconomic releases. To estimate the total impact of the program as the sum of the event set impacts, the authors employ the Gagnon et al. (2011) assumption that all changes in expectations occur during the event set. The main finding is that the APP lowered yields on long-term, sovereign bonds by 30-50 basis points, with even greater effects on higher yielding bonds, such as those of Italy and Spain.

4.11 SNB asset purchases and the role of reserves

The SNB introduced some unusual asset purchase/quantitative easing programs that allow researchers to investigate hypotheses regarding the channels of UMP for a central bank of a small open economy. Specifically, on March 12, 2009, the SNB announced its intention to buy private bonds to reduce risk premia and private funding costs, but provided few details on the size of the program or the types of bonds. The SNB simultaneously announced it would purchase CHF 3 billion of mortgage-backed covered bonds and non-financial corporate bonds which was 0.5% of Swiss GDP or 5% of the Swiss covered bond market.

Using graphical and regression analysis Kettemann and Krogstrup (2014) document a delayed reaction to this SNB purchase announcement of March 12, 2009. A few days after the SNB announcement, covered bond spreads — the spread over the Swiss Confederation bond with the same maturity — declined substantially but neither corporate bonds nor bank bond spreads shared that fall. The authors argue that the ambiguity of the initial announcement delayed the decline in covered bond spreads. Although simultaneous policy initiatives that influence short rates preclude the authors from estimating a separate signaling effect, they attribute a 10 b.p. decline in the term premium for mortgage-backed covered bonds to a portfolio balance effect. The SNB sold these bonds during March to August 2010 — well before the Kettemann and Krogstrup (2014) study — but this unannounced exit produced no observable

71 The Fed and the BOJ would both act on March 18, 2009.
effect. Of course, gradual, unannounced sales over five or six months imply small, gradual changes to interest rates that may be difficult to detect.

To counter deflationary trends and the appreciation of the CHF, the SNB announced further expansionary policy in early August 2011. In successive weeks, on August 3, 10 and 17, the SNB lowered the top of the target range for the three-month CHF LIBOR from 75 to 25 basis points and expanded reserves from CHF 30 to 80 to 120 to CHF 200 billion. The SNB would engineer this expansion by buying SNB bills and with foreign exchange swaps, not by purchasing long bonds. Therefore, this reserves expansion should have produced no traditional portfolio balance effect because it did not reduce the duration of publicly held securities or remove long bonds from the market. But Bernanke and Reinhart (2004) had previously suggested that expanding reserves could produce a portfolio balance effect because reserves are a special asset, held only by banks. Therefore, banks must rebalance their asset/liability portfolios if they must hold more reserves.

Using TSM/event study methods, Christensen and Krogstrup (forthcoming) confirmed the Bernanke and Reinhart (2004) portfolio balance effect: The SNB reserve expansion substantially reduced long rates (28 b.p.) with no appreciable signaling, except for the first announcement. Christensen and Krogstrup (forthcoming) attribute the lack of signaling to a lack of contemporaneous forward guidance. The paper implies that management of reserves may be an important policy tool, even without a change in duration in the hands of the public.

4.12 Riksbank asset purchases

In February 2015, the Riksbank announced the purchase of SEK 10 billion of 2- to 11-year government bonds. Concerns about the strengthening of the Swedish krona (SEK) prompted the Riksbank to extend its bond purchases four times and it also lowered the repo rate to -0.35 percent in July 2015 and -0.50 percent in February 2016. The Riksbank sought to lower yields to encourage bank lending, to forestall appreciation of the Swedish krona and, ultimately, to stimulate the economy and achieve the 2 percent inflation target.

De Rezende (2017) contributes to our knowledge of two issues, one methodological and one substantive: 1) How can one separately estimate the marginal effects of multiple policies — conventional and unconventional — that are announced simultaneously? 2) Can a central bank in a small open economy affect long yields?

To separately assess the effects of bond purchase announcements from conventional policy shocks, De Rezende (2017) uses a TSM along with a regression event study of 6 monetary policy announcement events from February to October 2015. Four of those six events had simultaneous

72 On September 6, 2011, the SNB announced a minimum value for the CHF of 1.20 CHF/EUR and stated its willingness to defend that peg.
announcements of changes to the repo rate and the asset purchase program, while all, in principle, communicated news about both types of policy. De Rezende (2017) estimates a model from pre-2015 data to pin down the effects of conventional target and path shocks on the whole yield curve. The author then subtracts this model’s post-2015 fitted values from yield curve changes on days of bond purchase announcement to measure how those announcements affect yields. Conventional policies affected mostly the short end of the yield curve while bond purchase announcements influenced medium and long yields through the portfolio balance effect, reducing Swedish long yields by 46 basis points from a low initial level. The author concludes that conventional and unconventional policies can complement each other.

4.13 Financial institutions

The health and behavior of financial institutions directly affects how and whether UMP affects the rest of the economy. A series of papers have looked at how UMP has affected financial institutions and how those institutions have reacted to it.

Lambert and Ueda (2014) study the effect of U.S. monetary policy on bank stock valuation, risk, profits and balance sheet condition, using both high frequency, event-study regressions of bank stock prices and credit spreads on monetary surprises and low frequency panel regressions using balance sheet data. In addition to using standard path surprises, the authors create their own novel instrument for monetary surprises from Factiva news coverage of each policy event. Using a sample with all FOMC announcement days from January 2000 until October 2012, event study regressions show that a surprise “path” easing has no significant effects on bank stocks in either the conventional or unconventional period and that UMP shocks have no strong, consistent effects on credit spreads. These results contrast with the conventional wisdom.

Panel regressions with balance sheet data show UMP shocks (i.e., deviations from the Taylor rule and related specifications with the yield curve) don’t affect bank profitability but do allow banks to reduce leverage and extend the maturity of their liabilities. However, UMP shocks appear to raise the ratio of risk-weighted assets to total assets and delay balance sheet repair.

According to Chodorow-Reich (2014), UMP potentially affects the financial sector by lowering the hurdle rate for investment, causing institutions to seek higher returns, lowering risk by promoting recovery and reducing the opportunity cost of holding reserves. Chodorow-Reich’s (2014) event study of 14 surprising Fed policy changes from December 1, 2008 through September 13, 2013 shows that UMP announcements raised stock prices and reduced CDS rates for banks and life insurance companies. In addition, the author finds that relatively high-cost money market funds “reached” for higher returns in 2009-11, but not after that period.

Vissing-Jorgensen (in Lucas, D., & Vissing-Jorgensen, A. (2014)) forcefully argues that Chodorow-Reich’s (2014) standard error in the event study — constructed from separate cross-section regressions — understate the true uncertainty about the coefficients, although many of the events would still produce statistically significant effects.
Discussions of Chodorow-Reich (2014) by Lucas and Vissing-Jorgensen (2014) argue that the effect of lower yields on risk taking is theoretically indeterminate while Vissing-Jorgensen suggests that UMP has increased risk-taking over time. Vissing-Jorgensen further argues that the Chodorow-Reich (2014) study would be even more valuable if it shed light on the channels through which UMP affected insurer and bank stock prices and CDS rates.

Motivated by the plausibility of preferred habitat models, Carpenter et al. (2015) investigate how QE1, QE2 and MEP (until 2013) transactions have led investors to rebalance their portfolios. The authors construct 8 categories of investors from quarterly, Fed flow-of-funds data, which describes asset holdings by asset and type of agent. The authors regress quarterly changes in the holdings of all types of agents on changes in the Fed’s holdings and control variables, finding that only a few types of investors ultimately sell bonds (on net) to the Fed. Households (including hedge funds), broker-dealers, and insurance companies sell off Treasuries while households, investment companies, and pension funds unload MBS. Net sellers rebalance their portfolios toward riskier assets during this period, which the authors interpret as supporting the preferred habit theory. Households tend to shift portfolio weights toward higher yielding bonds and bills—corporate bonds, commercial paper, and municipal debt—while pension funds invest in repos or other very short-term assets.

Using both net investment data from national accounts and micro-data from regulatory sources, Joyce, Liu, and Tonks (2017) investigate whether BOE QE influenced the portfolio choices of insurance companies and pension funds (ICPFs) in a manner consistent with the portfolio balance channel of UMP, which would imply that ICPF s would replace gilts with higher-yielding but riskier assets. The authors estimate the reaction of firms’ asset allocation by times-series panel regressions of bond acquisition (bond shares) on BOE purchases, Treasury debt issuance, financial controls and lagged values of the dependent variable over 1987Q1–2012Q4. The paper finds that QE prompted financial institutions to sell gilts in favor of corporate bonds but not to shift into equities. Quantitatively, the effect was substantial: £375 billion of QE purchases prompted ICPF to purchase £117 billion of corporate bonds, or twice the average annual gross corporate bond issuance in the U.K. during 2003–08.

Koijen et al. (2017) characterize how investors rebalance their portfolios in response to the ECB’s expanded asset purchase program of January 22, 2015. The authors argue that the euro area, which collects data on securities holdings by asset class, by country and investor sector, provides uniquely useful data for examining portfolio rebalancing and therefore the channels by which bond purchases influence the economy. The authors employ cross-country variation in ECB asset purchases to identify effects. Koijen et al. (2017) find that foreign investors and banks

---

74 The 8 categories are as follows: rest of the world, depository institutions (DIs), insurance companies, investment funds, pension and retirement funds, state and local governments, broker-dealers, and households (including hedge funds).

75 The regulatory authorities are the Prudential Regulation Authority (PRA) and the Pensions Regulator.
sold purchase-eligible government bonds, on net, while insurance companies and pension funds bought them. The authors note that the fact that foreign investors sold the purchase-eligible bonds is surprising, considering that a version of Ricardian equivalence might imply that domestic investors—who collectively own the ECB asset holdings—should sell those purchase-eligible bonds to offset the risk that the ECB has purchased on their behalf.

Central bank asset purchases do prompt financial institutions to rebalance their portfolios toward riskier assets, which can vary, depending on the country and period. Shifts toward corporate bonds have been substantial. But rebalancing does not always occur in the way that one might think. For example, foreign investors, not domestic investors, sold purchase-eligible bonds in response to ECB asset purchases.

### 4.14 Negative interest rates

The central banks of a number of monetary areas—ECB, Sweden, Switzerland, Denmark, Hungary and Japan—set negative deposit rates during the post-crisis recovery, the hopes that such negative rates would lead financial institutions to lower other interest rates and perhaps boost asset prices.

While the transmission of negative interest rate policy might produce effects similar to those of interest rate cuts at positive interest rates, negative interest rate policy may also have specific costs, which probably explains why more central banks have not adopted it. In particular, policymakers have sought to avoid reducing bank profitability if banks are unable to push their own retail lending rates negative. Moreover, banks might perversely opt to reduce lending as well, especially if leverage constraints bind.

Bech and Malkhozov (2016) describe the policies and outcomes of the four European central banks—Danmarks Nationalbank (DN), the ECB, Riksbank, the SNB—that moved deposit rates negative from mid-2014 to early 2015 and kept them below zero for at least a year. Moderately negative rates are broadly transmitted to wholesale money markets but generally not to retail markets (i.e., deposit rates). In wholesale markets, some banks have used negative-rate exemption schedules similar to those employed by central banks on reserves. Certain potential money market problems have not occurred, such as counterparties strategically delaying collateral delivery to delay receiving cash. Intuitively, the authors conjecture that a longer period of negative rates or deeper negative rates may raise the ELB as firms and individuals adjust to minimize their interest costs. The paper does not attempt to assess the effect of negative rates on welfare or the overall financial system, including the profitability of financial firms.

Arteta et al. (2016) study the effects of negative interest rate announcements by five central banks (i.e., the ECB, Riksbank, DN, SNB, and BOJ) with an event study with one-day windows. By pooling over times and across countries, the authors obtain a 17-observation sample. The event study indicates that negative interest rate announcements reduce money market rates and government yields by a few b.p., had mixed effects on exchange rates and no effect on inflation.
expectations. The effects were very heterogeneous across countries. For instance, ECB policy announcements barely decreased government bond yields.

While short samples and other, simultaneous UMP measures make it difficult to formally evaluate negative interest rate policies, International Monetary Fund (2017) provides casual evidence that negative interest rates gradually decreased deflationary and/or appreciation pressures in Sweden, Denmark, and Switzerland. The BOJ’s announcement of negative rates in January 2016, which was clearly unexpected as the Bank had earlier ruled out negative interest rates, produced strong financial reactions: the Japanese yen depreciated broadly and stock prices rose. The strong transmission of negative rates to foreign exchange markets, which interact with wholesale money markets, is intuitively appealing but not necessarily robust (Fukuda (2017)).

Motivated by the possibility that Japan’s QQE may have had positive spillovers on international financial markets, Fukuda (2017) employs graphical analysis and regressions to characterize the impact of Japan’s negative interest rate policy (NIRP) on Asian financial firms. Expansionary UMP announcements that did not include negative interest rates (QQE1 and QQE2) raised Japanese equity prices and depreciated the JPY but Fukuda (2017) shows that expansionary announcements with negative interest rates (NIRP1 and NIRP2) attenuated those previous equity and exchange rate responses. Introducing the NIRP also changed the reaction of Asian stock prices to JGB yields, except in Korea. Prior to the introduction of negative interest rates, Asian stock prices did not react to 10-year JGB yields but did start reacting negatively after that policy. During the NIRP period, declines in 10-year JGB yields significantly increased Asian stock prices, except for those of Korea, because such reductions sent Japanese financial firms searching abroad for higher-yielding foreign assets. Thus, Japanese negative interest rate policy generated negative (positive) excess returns for the Japanese (other Asian) financial sector.

Negative interest rates appear to have had only very modest effects on interest rates, stock prices and exchange rates, on average, and the effects are heterogeneous across countries. The introduction of such negative rates in Japan, however, changed the relation between Asian stock prices — particularly those of financial firms — and 10-year JGB yields.

4.15 Surveys and overviews

A series of papers have sought to survey and/or evaluate the conclusions of parts of the literature on UMP. Of these papers, asset purchases seem to have drawn the most attention. Some of these survey/overview papers have been very positive about the impact of UMP while others have been more skeptical, some minimizing or denying any positive impact. The obvious positive financial market impacts of the early asset purchase programs generated some initial confidence in their efficacy. For example, Bullard (2010) argued that the evidence had already

76 The authors thank Matt Rognlie for the suggestion that exchange rates might be sensitive to negative interest rates.
showed that asset purchases can substitute for conventional monetary policy to some extent and that connections between asset prices and monetary policy are important.

Academics soon began to turn a jaundiced eye — as they should — toward such claims. In an early overview of the literature, Martin and Milas (2012) acknowledged that although event studies showed central bank asset purchase announcements had significant effects, such effects may be temporary and later programs may have had smaller impacts. On the positive side, these authors suggest that UMP prevented an even larger recession in 2008-2009. Martin and Milas (2012) also complained, however, that the literature on asset purchases relies too heavily on limited methods, such as event studies, and draws too heavily on central bank researchers who are presumably biased.

Joyce et al. (2012) introduce a special issue of the Economic Journal that published articles presented in a BOE conference on UMP. These authors note that UMP is heterogeneous and should not be thought of as a magic bullet. They suggest that future research should examine the costs of increasing UMP and they advocate improved regulation to avoid financial crises.

Gagnon (2016) presents a very sanguine picture of the literature on international central bank asset purchases. The author interprets the UMP literature to indicate that a wide consensus exists among economists who have studied QE that such purchases can ease financial conditions and support economic growth through channels similar to those of conventional monetary policy. But the same consensus does not yet exist in the wider economics profession or in the wider policy world, however. UMP can be particularly powerful during times of financial stress but is not restricted to those circumstances. Asset purchases can influence economic growth and inflation in standard macroeconomic models. Gagnon (2016) also rejects the idea that the portfolio balance channel has had diminishing returns, as argued by Martin and Milas (2012), Habermeier, Jacome, and Mancini-Griffoli (2013) and Borio and Zabai (2018), among others, but he states that the signaling channel may have diminishing returns.

Greenlaw et al. (2018) take a much more skeptical view of the Fed’s asset purchase policies. These authors estimate that the consensus view is that the Fed’s total asset purchase programs reduced 10-year yields by approximately 100 b.p. but argue that this significantly overstates the true impact. While acknowledging that some surprisingly expansionary FOMC announcements reduced yields significantly, the authors argue that estimating effects from a limited set of FOMC events with known asset purchase news biases estimates of program impact upward. They reason that because markets had come to anticipate a possibility of expansionary announcements at every FOMC event — which reduced yields slightly — those events in which

77 Even authors who are skeptical of the benefits of asset purchases usually accept that a number of the Fed’s expansionary announcements significantly reduced yields. Thornton (2017) may be a unique exception in disputing the event-study evidence showing substantial changes in asset prices at the precise times of surprisingly expansionary Fed announcements.
the FOMC did not announce an expansion tended to produce small increases in yields, which should be counted against the total effect of the program. The authors also argue that non-monetary news was more important than UMP in determining the 10-year yield and that the impact of UMP events tended not to persist (Wright 2012, Swanson 2017). Finally, the authors argue that an unexpectedly hawkish transition to a smaller balance sheet path did not produce much of a reaction and that even the famous “Taper Tantrum” was more about good economic news than a reduction of Fed stimulus. In summary, the authors argue that the LSAPs have had some effects through the portfolio balance channel but that these effects are much more modest than are generally claimed.

Figure 10 — excerpted from Neely (2014) — indicates that much of the “Taper Tantrum” was indeed about monetary policy. The top (bottom) panel of Figure 10 shows movements in the 10-year Treasury yield (foreign exchange value of the USD) from midnight June 19, 2013 to 6 pm (EST) June 21. In particular, both the long-term U.S. bond yields and the foreign exchange value of the dollar relative to other major currencies rose substantially at the time of Chairman Bernanke’s press conference at which he suggested that the Fed might reduce its bond purchases later in 2013. This strong reaction to the suggestion of reduce bond purchases is consistent with the similarly strong, opposite reaction to unexpected Fed QE1 asset purchase announcements. Figure 10 seems to illustrate that asset purchase programs have had the desired effect on asset prices and probably also influenced output, employment, and inflation expectations in the desired direction.

Greenlaw et al. (2018) also argue that negative interest rates have “limited potential” as monetary tools and that forward guidance, which is theoretically attractive, is difficult to implement in practice. The authors argue that the weaknesses of UMP mean that conventional short-term interest rate management should be the primary Fed tool going forward.

While conceding that the Fed’s QE1 could have produced unusually large effects that would be difficult to repeat in less turbulent times, Gagnon (2018) criticizes the analysis of Greenlaw et al. (2018) on several grounds. First, Gagnon (2018) suggests that they neglected the importance of market expectations in later rounds of asset purchases. That is — as discussed previously — Greenlaw et al. (2018) interpret the smaller market reaction to later rounds of asset purchase announcements as indicating much smaller effects of those programs rather than markets learning to anticipate Fed asset purchase programs. Second, Gagnon (2018) points out that Greenlaw et al. (2018) missed a couple of important expansionary announcements in their calculations, which reduced the estimated asset purchase effects. Finally, Gagnon (2018) buttresses event study results with reference to similar inference from the regression analysis in Gagnon et al. (2011). 

Although Greenlaw et al. (2018) make serious arguments for caution in interpreting the effects of asset purchases and other UMP measures, the authors of the present paper, Neely and Bhattarai, broadly agree with Gagnon’s (2018) reasoning. We would also point out that estimates
of QE1 effects are larger with small event sets but they are still fairly large with large event sets (Gagnon at al. (2011)). We also agree with Gagnon that calculating the total effect of programs after QE1 is extremely difficult because markets had come to expect Fed UMP and were constantly reevaluating the distribution of future policy. That is, expectations were changing all the time.

Foerster and Cao (2013) take precisely the opposite view from Greenlaw et al. (2018) on the issue of bias in the estimation of asset purchases. The former authors argue that the effects of asset purchases occur as expectations about those purchases change and one should assess their impact on the basis of all changes in yield caused by changes in program expectations, not just those changes in yields that occur at announcement times. Focusing on Fed purchase announcements from 2008-2012, the authors use evidence from surveys of market participants, news, and Internet searches to show that market expectations of asset purchases and associates yields were changing prior to LSAP announcements. Therefore, the authors argue, standard event studies tend to underestimate the effect of asset purchases because they ignore these changes in expectations.

Second, we also take issue with Greenlaw et al.’s (2018) estimates of the persistence of shocks to yields. Theoretically, asset prices should be discounted, risk-adjusted estimates of future prices and so changes in those asset prices should be fairly unpredictable, with the degree of predictability a positive function of the risk aversion of the marginal investor. Any shock to an asset price should be fairly persistent, that is, minimally predictable. Too much predictability is inconsistent with rational markets because speculative forces should trade to reduce it. Empirically, many studies have claimed to predict asset returns but were later overturned by more careful study or out-of-sample evidence. Thus, it is hard to take econometric findings of limited persistence at face value, as such findings have so often turned out to be wrong. Neely (2016) makes these points in criticizing Wright’s (2012) argument that Fed shocks were transient.

Third, Greenlaw et al. (2018) sometimes make arguments that do not really reflect the effectiveness of asset purchases, such as stating that other variables were more influential on yields than were Fed asset programs — which may be true but is not relevant to whether UMP should be used — or conjecturing that Treasury later undercut the effect of the Fed’s asset purchases by lengthening the maturity of the Treasury’s offerings. These may well be true but are not really relevant to the issue of the effect of asset purchases.

With respect to Treasury policy, Greenlaw et al. (2018) make the excellent point that the Treasury should follow up on recent moves to make its decisions about the maturity composition of the Treasury’s offerings more systematic and model driven. The authors correctly argue that this would prevent the Treasury from working at cross-purposes with Fed policy.
One might reconcile — to some degree — the very positive view of Gagnon (2016) with the much more skeptical stance Greenlaw et al. (2018) by noting that even after a plethora of studies of various types on international data, there is considerable uncertainty about the effects of UMP, including asset purchases and that some of the apparent disagreement lies in whether to emphasize that asset purchases have almost certainly produced substantial effects on yields or whether to question if such yield changes are as big or as persistent as often claimed.

5. Macroeconomic effects of unconventional policies

Studying the effects of unconventional policy on the macroeconomy is both more important and more difficult than studying policy effects on asset prices and yields. It is more important because central banks wish to influence output, inflation and, ultimately, consumer welfare. It is also more difficult because endogeneity, simultaneity, omitted variables, specification error and measurement errors are much more serious problems for macro studies than for financial markets, which are amenable to using “event studies” to gauge policy effects.

The literature on the effects of UMP follows the larger empirical macro literature in using calibrated DSGE models and VARs. Each method has advantages and disadvantages. Simulations from calibrated DSGE models can more easily assess the relative importance of particular channels, e.g., signaling vs. portfolio balance, but are presumably more dependent on the assumed structure of the economy and the specific mechanism built in the model. In contrast, VARs are necessarily more agnostic about the structure of the economy and the precise mechanism by which quantitative easing has effects, and may therefore be less prone to misspecification and can conveniently summarize the overall dynamic effects of policy shocks.

5.1 Calibrated/estimated DSGE Models

One can assess the macroeconomic implications of the financial market effects of LSAPs identified by event-studies by using calibrated DSGE models that feature a role for UMP. Specifically, a DSGE model can be simulated with and without UMP interventions in an ELB situation to assess the distribution of paths for variables of interest, such as output and inflation. The policy intervention can be sized to resemble a particular asset purchase episode, such as the Fed’s QE2, or with a change in the composition of a central bank’s balance sheet, as in the Fed’s MEP. Moreover, researchers can impose financial market effects, which were identified by other methods such as event-studies, of an UMP intervention on model dynamics. The difference in model outcomes from the policy intervention then measures the model-implied macroeconomic effects of the intervention.

Researchers have used such a strategy to assess the macroeconomic effects of the portfolio balance, limits-to-arbitrage due to leverage constraints, and signaling channels of asset purchases. Chen, Curdia, and Ferrero (2012) calibrate a DSGE model with a role for the portfolio balance channel, to assess the effects of asset purchases. A $600 billion purchase of long-term
government bonds (matched to the Fed’s 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 b.p. (both annualized) on impact, and reduces the term-premium by 11 b.p. on impact. The peak effects occur on impact in the simulations. Importantly, 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.

In a calibrated model that features limits to arbitrage due to financial intermediaries facing binding leverage constraints, Gertler and Karadi (2013) find that a $600 billion purchase of long-term government bonds, together with a credible commitment to hold short-term interest rates at zero for four quarters and a calibration to reduce the ten-year Treasury yield by 12 b.p., produces a peak increase in output of around 1% and inflation of around 1.4 b.p.. Like Chen, Curdia, and Ferrero (2012), Gertler and Karadi (2013) also find that the bulk of the effects (around 80%) is due to the credible commitment by the central bank to hold short-term interest rates at zero in future. This suggests that asset purchases that improve financial intermediation in the economy and decrease excess returns are most effective in a scenario where the central bank policy rate is expected to be kept near zero for a considerable time.

The fact that Chen, Curdia, and Ferrero (2012) and Gertler and Karadi (2013) 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 indicates that the signaling channel can be powerful in DSGE models. This should be expected, however.

Bhattarai, Eggertsson, and Gafarov (2015) calibrate their DSGE model, which features a role for the signaling channel due to the inability of the central bank to credibly commit to a policy path, to match the signaling effects of the Fed’s QE2 on financial markets from Krishnamurthy and Vissing-Jorgensen’s (2011) event-study estimates. 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 expansionary effects of quantitative easing on the economy. As we described above, Bhattarai, Eggertsson, and Gafarov (2015) provide two model based interpretations for quantitative easing. In the first model with coordinated monetary and fiscal policy, where quantitative easing shortens the maturity of outstanding government debt, the Fed’s QE2 and MEP increase output on impact by about 30 and 90 b.p., respectively and inflation by about 14 and 90 b.p., respectively. The results suggest that QE2 under this interpretation stimulated the U.S. economy less effectively than the MEP.

In the second model with an independent central bank, where quantitative easing expands the central bank balance sheet under QE2 and changes the asset composition under MEP, QE2 and the MEP increase output on impact by about 45 and 12 b.p., respectively and inflation by about 14 and 2.5 b.p., respectively. Under the assumption of an independent central bank, QE2 stimulated the U.S. economy more effectively than the MEP. Overall, one common theme across
these all three papers is that they find that the central bank’s commitment, either directly or indirectly, to hold short-term interest rates at zero produces the bulk of the quantitative effects of asset purchases. These models have expectations of short rates built into them, but they do not have savers and investors with specific preferences for segments or interesting portfolio balance problems that would produce effects on the term premium.

The theoretical frameworks discussed above have also been used to estimate macroeconomic effects of unconventional monetary policy that are not strictly asset purchases. For instance, Cahn, Matheron, and Sahuc (forthcoming) apply the framework of Gertler and Kiyotaki (2010), which introduced a role for discount lending, to study the effects of ECB’s LTRO policies. These authors first extend the set-up in Gertler and Kiyotaki (2010) for long-term lending and then estimate a quantitative DSGE model using euro-area data on both macroeconomic and financial variables. The two important findings are: first, a one-time 12-month exogenous LTRO, of an amount 2% of annual GDP, leads to macroeconomic effects comparable to a 25 b.p. cut in the short-term interest rate; second, absent the 6-month and 12-month LTROs, output and GDP deflator would have been 2.5% and 0.5% lower on average over 2009. The key mechanism for these macroeconomic effects is again the reduction in credit spreads, which is at the heart of the transmission of policy in the limits-to-arbitrage models. Thus, absent the 6-month and 12-month LTROs, credit spreads would have been 400 b.p. higher.

5.2 Identified VARs

The second and more theoretically agnostic method of assessing the effects of unconventional policies on the macroeconomy is with vector autoregressions (VARs). VARs summarize the auto/co-variance structure of monthly policy shocks and other variables, such as output and price. They require fewer explicit assumptions about the behavior of consumers and firms than do DSGEs but they also make it more difficult to infer the relative importance of the channels of monetary policy. A table in Appendix B details the methods and data from the VAR studies discussed in Section 5.2.

The need to identify and measure UMP shocks are the biggest hurdles to using VARs to assess UMP policy. Although the federal funds rate, often augmented with “path” shocks, is widely accepted as the appropriate instrument of conventional monetary policy, the definition of an UMP instrument is more controversial. Conditional on the measure of unconventional policy, however, VAR studies have used identification restrictions that are similar to those used in the conventional monetary policy literature, such as contemporaneous restrictions that the policy shock affects the macroeconomy with a delay or sign restrictions that an expansionary policy shock has a positive effect on output and prices. Such identification restrictions, while certainly debatable, have been both widely used and critically assessed in the pre-crisis literature.

78 Path shocks are essentially equivalent to the one-year forward rate. Gürkaynak, Sack and Swanson (2005) argue that they result from FOMC communication with the markets.
Finally, VARs on UMP samples can produce imprecise estimates compared to estimates from the conventional monetary policy literature because the typical UMP sample is much shorter than the conventional policy sample.

5.2.1 VARs with central bank assets as the monetary instrument

The first set of VAR papers use a measure of the asset side of the central bank’s balance sheet as an unconventional policy instrument, either actual asset purchases or announced purchases. For instance, Gambacorta, Hofmann, and Peersman (2014), in an early study, estimate a panel VAR on monthly output, price, VIX and central bank assets data from 8 monetary areas — 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 shocks, the authors find that an exogenous increase in central bank assets, which they consider to be the monetary policy instrument at the ELB, temporarily increases output and prices. A 3% increase in assets of the central banks has peak effects on output and prices, which occur after 6 months, of around 0.038-0.098% and 0.008-0.042% respectively.

In a related paper, Boeckx, Dossche, and Peersman (2017) study effects of ECB unconventional policy using a VAR identified with both contemporaneous (i.e., zero) and sign restrictions. They use data from January 2007 to December 2014 on ECB total assets, and macroeconomic prices and quantities as well as financial indicators. Impulse response analysis implies that an exogenous increase in assets held by the ECB temporarily raises output and prices. Such a balance sheet shock affects the economy through an increase in the volume of bank lending and a decrease in interest rate spreads. In a counterfactual exercise, the authors find that output and inflation would have been more than 1% lower in 2012 without the 3-year LTRO. In this exercise, the effects of LTRO are assumed to come from expansion of the central bank asset and in particular, the shock to the size of the ECB balance sheet is €316 billion in December 2011 and €272 billion in March 2012.

Gambetti and Musso (2017) use a time-varying VAR to ascertain the macroeconomic effect of PSPP by the ECB. The authors use data from 2009-2016 and define the UMP instrument as securities purchased by the Eurosystem. They then identify a PSPP shock in the first quarter of 2015 using a set of sign, magnitude, and timing restrictions. A key component of the identification is that the securities-purchased shock reduces 10-year sovereign yields on impact, while it increases GDP and inflation with a lag (leaving the impact effect unrestricted). Counterfactual analysis implies that the impact effect (that is, the effect on the first quarter of 2015) of the PSPP shock (around 10 billion) on GDP was 0.18 percentage point while on inflation it was 0.06 percentage point. While these effects are small, it is perhaps to be expected given that the PSPP was a small UMP intervention.

In a similar approach, but with a focus on international spillovers of U.S. QE policy, Bhattarai, Chatterjee, and Park (2015) estimate the impact of U.S. QE using a Bayesian VAR
with contemporaneous restrictions, under the assumption that assets purchased outright — as opposed to announced intentions to purchase — functions as the instrument of UMP. The authors estimate the model on monthly U.S. and emerging market data from January 2008 to November 2014. Unanticipated fluctuations in the instrument substantially influence asset prices in emerging market economies. A 2% increase in Fed securities purchases (which is a one standard deviation shock and about $40 billion) has an impact effect of 25 b.p. on the nominal exchange rate, 100 b.p. on emerging market stock prices, and 3 b.p. on long-term yields of emerging market economies. Moreover, capital inflows to emerging markets increase by around 2% at peak. Additionally, the paper provides evidence of heterogeneous reactions among emerging market economies, with stronger effects on the so-called “Fragile Five” countries (Brazil, India, Indonesia, South Africa, and Turkey).

Among advanced economies, Japan has had the longest experience with ELB and UMP. Researchers have used similar methods to evaluate BOJ’s UMP programs. For instance, Schenkelberg and Watzka (2013) identify the impact of BOJ’s QE programs using a Bayesian VAR with sign restrictions. The UMP instrument is assumed to be bank reserves held at the BOJ (termed “current account” balances by the BOJ) from March 1995 to September 2010. The authors estimate the model on monthly Japanese data, and find that a QE shock that increases reserves by 7% leads to an increase in output by 0.4% at peak, after 2 years, while significantly decreasing 10-year JGB rates, with an impact effect of 0.07 % points. The effects on consumer prices however are small and transient.

Hayashi and Koeda (forthcoming) also estimate the impact of BOJ’s QE programs using a regime-switching VAR approach. Unlike Schenkelberg and Watzka (2013), they use excess bank reserves held at the BOJ as the UMP instrument. Under the first regime, the central bank has a standard interest rate reaction function, operating at positive interest rates, while during the second regime, which governs at the ELB, the BOJ’s policy rule determines the supply of excess reserves under QE. The Hayashi and Koeda (forthcoming) model also incorporates forward guidance by positing that the BOJ will exit QE only if interest rates exceed the ZLB and inflation exceeds a threshold. These features endogenize the regime switches. An estimation using monthly data from Jan 1988-Dec 2012, implies that an exogenous increase in excess reserves by the BOJ increases the output gap and inflation: an increase of excess reserves of 10% of GDP leads to a peak effect of about 1.4% on the output gap after 10 months and a peak effect of about 0.55% on inflation after 1 month. The effects on the output gap are quite persistent but those on inflation are transitory. Both Schenkelberg and Watzka (2013) and Hayashi and Koeda (forthcoming) thus find that the BOJ’s QE policies had stronger and more persistent effects on
output than inflation. This accords with the significant difficulty that Japan has faced in raising inflation.\textsuperscript{79}

A significant difficulty with using assets held, securities purchased, or central bank (excess) reserves as a QE instrument is that financial asset prices almost certainly change with expectations (announcements) and therefore such price changes and macroeconomic effects might precede the purchase of the securities. That is, quantities purchased can considerably lag the effects of the announcement. Therefore, Weale and Wieladek (2016) assume that the QE policy instrument is the cumulated level of announced asset purchases (scaled by GDP) by the Fed and BOE, as opposed to actual purchases, for the period Mar 2009- May 2014. Although it is difficult to assess the effects of open-ended programs in this approach because the total quantity of purchases is contingent on economic developments, these authors find that an asset purchase announcement of 1% of GDP by the Fed has peak effects on U.S. real GDP of 0.58% and CPI of 0.62%. Moreover, an asset purchase announcement of 1% of GDP by BOE has peak effects on U.K. real GDP of 0.28% and CPI of 0.32%.

5.2.2 \textit{VARs with an interest rate spread as the monetary instrument}

Unlike the first set of VAR papers described above that used quantities on the central bank balance sheet as an instrument for QE policy, a second set of VAR papers has used an interest rate spread—typically mortgage spread or long-term Treasury spread—as a metric for QE policy. Starting with a given estimate of the effects of QE on interest rate spreads, these papers identify the effects of a spread shock with existing restrictions and then indirectly assess the macroeconomic effects of QE. This indirect but plausible method utilizes the substantial evidence, especially those from event-studies, of the effects of QE on interest rates/spreads.

In particular, Walentin (2014) uses contemporaneous restrictions to first isolate shocks to mortgage spreads — the mortgage rate less the Treasury rate of the same maturity — and then sizes the policy shock with event study estimates of the QE1 effects on mortgage spreads, as well as VAR estimates of the decline in mortgage spreads during the QE period. In particular, using the Hancock and Passmore (2011) estimate that QE1 reduced mortgage spreads by 150 b.p., Walentin (2014) finds that QE1 increased consumption and GDP by 3.2 and 3.8 percentage points at peak, respectively, while residential investment and house prices increase by 12.1 and 5.1 percentage points respectively.

\textsuperscript{79} For decades, the monetary policy literature has emphasized the importance of expectations for managing inflation. Ito and Mishkin (2006) broadly review the monetary literature in the context of the Japanese experience from 1999-2006. The literature concludes that deflation is costly — particularly prolonged deflation as in Japan — and is difficult to end. Ito and Mishkin criticize the BOJ for managing market expectations poorly, such as terminating the zero interest rate policy (ZIRP) in 2000, before deflation was fully stopped, although the authors also suggest that BOJ expectations management improved later in the sample.
Using a similar approach, Baumeister and Benati (2013) employ a time-varying parameter VAR framework with sign restrictions to identify a “pure” term spread shock — long rate less current short rate — that leaves the federal funds rate unchanged but affects the 10-year Treasury yield. The authors estimate that reducing this interest rate spread produces substantial macroeconomic effects during the ZLB period. Then — sizing the effects of asset purchases on the long-term interest rate spread with estimates by Gagnon et al. (2011) — the authors infer that LSAPs averted deflation and an output collapse. In particular, had the Fed asset purchases during QE1 not compressed the ten-year Treasury yield spread by 60 b.p., inflation would have dropped by 1 percentage point and output growth reached a trough of -10%.

Baumeister and Benati (2013) also study the effects of BOE asset purchases. Using Deputy Governor Bean’s (2009) estimates of the effects of U.K. QE1 on the long-term interest rate spread, the authors infer that asset purchases averted deflation and an output collapse for the U.K. as well. In particular, had the BOE’s QE1 not compressed long-term yield spread by 50 b.p., inflation would have dropped by 4 percentage point and output growth reached a trough of -18%. Kapetanios et al. (2012) also use a VAR framework, including time-varying variants, with the same counterfactual strategy as Baumeister and Benati (2013) to assess the macro effects of U.K. QE1. In a counterfactual exercise, using estimates from Joyce, Tong and Woods (2011) that long-term yields fell by 100 b.p. due to U.K. QE1, Kapetanios et al. (2012) infer that the peak effects of the BOE’s QE1 were 1.5% on real GDP and 1.25 % point on CPI inflation.

Chen et al. (2016) also use an interest rate spread measure to capture unconventional policy, but focus on international spillovers of U.S. QE policies. They first estimate an event study to characterize the impact of the Fed’s QE1 announcements on advanced and emerging economy asset prices, finding that QE1 raised equity prices, lowered bond yields and reduced CDS risk spreads. The authors then investigate macro effects with a vector error correction model (VECM) where they measure the U.S. unconventional policy shock as the estimated shock to the long-term U.S. term spread. In advanced economies (e.g., the G-7), QE1 produced little additional credit growth but had significant positive effect on growth and inflation rates, perhaps half those seen in the US. While there is no evidence that QE1 caused capital inflows to or credit growth in advanced economies, emerging markets displayed greater, although heterogeneous reactions. U.S. QE1 fostered capital inflows, domestic credit growth and inflationary pressures in some emerging economies. The heterogeneity in responses across emerging markets, as well as increased capital inflows to them, are consistent with the results in Bhattarai, Chatterjee, and Park (2015) described earlier, who used a quantity based measure of U.S. QE policies. Moreover, the authors report that some economies, such as Hong Kong, Brazil and Argentina, apparently showed greater expansionary impact from QE1 than did the U.S. itself.

5.2.3 VARs with a shadow short rate as the monetary instrument

Overall, the above studies that infer the macroeconomic effects of LSAPs through their effects on measures of interest rate spreads tend to find quite large effects. Another set of studies
measures the unconventional monetary policy stance in a VAR with shadow rates rather than with indirect and potentially confounding measures like interest rate spreads. Shadow rates can directly be interpreted as the central bank policy instrument. Bauer and Rudebusch (2016) show that shadow rate TSMs — which are constructed to account for the ZLB — forecast future short rates more accurately than conventional TSMs.

Wu and Xia (2016) use their shadow rate in a factor-augmented VAR to 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. They then compute a counterfactual for the ZLB period (2009-2013), in which the shadow rate stays at the lower bound, instead of becoming substantially negative as it did in reality. In the counterfactual exercise, which measures the effects if the Fed had not adopted any unconventional policy, the unemployment rate would have been 1% higher at peak than actually observed. Krippner (2017) argues that modest changes in the Wu and Xia (2016) specification produce a range of point estimates from 0.4 to 1.8%. While these macro effects are somewhat modest, they are nevertheless still non-trivial.

5.2.4 VARs augmented with survey data

Finally, while also using an identified VAR methodology, Darracq-Paries and De Santis (2015) use a slightly different approach to estimate the macroeconomic effects of the ECB’s LTRO program. The authors use information from the Euro Area Bank Lending Survey (BLS) to construct BLS credit demand and supply factors, and then use these as data in the VAR, in addition to using other relatively standard macroeconomic and financial variables. Estimating a panel VAR using data from 2003 through 2011 for two sets of euro area countries and using both impact and sign restrictions for identification, the authors study how 3-year LTROs affected real GDP and loan provision to non-financial corporations. The inclusion of the BLS factors first allows the authors to credibly identify an exogenous credit supply shock. A favorable credit supply shock leads to an increase in real GDP, a small but positive increase in prices, as well as a decrease in bank lending rate spreads, and an increase in outstanding amount of loans. Given these estimates, they next use unpublished, special BLS survey questions on the effects of the 3-year LTRO on credit standards to calibrate the size of the credit supply shock. They find that the 3-year LTRO shock has a modest but positive and hump-shaped impact on the level of euro area real GDP, inflation and bank loans to non-financial corporations, with peak effects on all variables coming in 2013 or 2014.

6. Discussion and conclusion

The severe, global financial crisis of 2007-2009 prompted central bankers to respond with massive liquidity and reductions in short-term interest rates to low levels. The constraint imposed by the ELB challenged central banks to find new monetary tools to stabilize financial markets
and stimulate their economies. Central banks responded with programs employing a variety of methods: Forward guidance, broad and narrow asset purchases, bank lending support, and negative deposit rates. The BOJ’s experiences in 1999-2006 had provided an early trial of versions of many of these tools.

Central banks tailored their UMPs to the structure of their economies and the problems facing them. For example, the Fed and BOE used mostly broad asset purchases to stabilize their important bond markets and stimulate their economies. The ECB and BOJ, whose economies were peripheral to the origins of the financial crisis and more dependent on banking, initially focused relatively more on programs to provide liquidity/funding to their banks but later added larger, broader asset purchase programs.

Recognizing the past and likely future importance of UMP, a rapidly growing and now huge literature modeled its potential effects and empirically evaluated its impact on financial markets and the macroeconomy. Despite the importance of such policies, most economists do not understand the research on UMP. This paper has analyzed the theoretical and empirical studies of UMP to more widely disseminate this knowledge.

Central bankers generally gauge the UMP programs as qualified successes in that they substantially improved financial conditions, reduced the magnitude of the recession and/or raised growth and avoided downside risks to price stability. The BOJ’s failure to raise Japanese inflation to 2% was a notable disappointment.

- “I don't think [Fed policies are] causing a danger. ... Is our policy a magic wand? No, it's not. But is it working? Yes, I think it is working.” — Janet Yellen (Yellen 2012)

Economists developed models based on several mechanisms — financial market frictions, participation constraints, leverage constraints, signaling effects under time consistent policy — that rationalize why asset purchases, the most important category of UMP, can influence the economy.

Event studies provide strong evidence that large central bank asset purchases moved asset prices in the desired direction, spilled over across markets, and prompted financial firms to reallocate their portfolios. Even narrow asset purchase programs appear to have normalized market functioning and encouraged intermediation, as did bank lending support programs. Results from other types of studies — e.g., low frequency regressions of yields on bond supplies — were generally consistent with those from event studies but were subject to econometric criticism. Some researchers have argued that existing event studies have exaggerated the effect of asset purchases and/or that the effects on yields are not very persistent. Again, other researchers dispute the methods of these critics and the issues are unresolved.

Fiscal deficits and debt management may provide one reason for findings of relatively transient UMP shocks. Greenwood et al (2014) estimate that U.S. Treasury lengthening the
maturity structure of U.S. debt may have offset 1/3 of the effect of Fed asset purchases on long yields, presumably reducing the beneficial impact. While their calculations were specific to the U.S., similar effects may be at work in other economies.

Studies of the macro effects of UMP generally employed DSGEs and SVARs. The quantitative DSGEs are built around a theoretical mechanism to give UMP some traction. SVAR researchers use both contemporary impact and sign restrictions to identify the impact of UMP policy shocks. In both the DSGE and SVAR literatures, researchers would often size policy shocks with reference to event study estimates of the total impact of a program.

UMP is useful because it allows central banks to stabilize financial markets and significantly influence output and inflation during periods when short rates are constrained from below. In addition to its positive effects on financial markets and the macroeconomy, however, UMP had negative effects that were either unforeseen or accepted as a necessary cost of the benefits of the policy. To take two examples, the Fed’s choice of assets in purchase programs could influence the impact of those transactions and the BOE FLS may have contributed to a substantial decline in international financial intermediation.

The financial crisis is now behind us and the Fed, ECB and BOE have moved toward normalizing policy. All three central banks have reduced or even reversed their asset purchases while the Fed and BOE have begun raising short-term interest rates. The goal seems to be to return to conventional monetary policy conducted through short-term interest rates, although the eventual size of balance sheets is not so clear. The Fed, which has been raising the funds target since 2015, is somewhat farther along this path than are the ECB or BOE, which were delayed by the euro sovereign debt crisis and Brexit, respectively. The BOJ has been unable to dislodge firmly held expectations of essentially zero inflation, which are now rooted in long experience.

As central banks return to smaller balance sheets and the use of short-term interest rates as the main policy tool, they must cope with a changed financial environment. For example, compared to the pre-crisis period, the Federal Reserve’s balance sheet will be much larger and reserves will be more plentiful for many years and perhaps indefinitely. With plentiful reserves, the Fed currently manages short-term interest rates with a combination of deposit rates (IOR) and reverse repos. Although the Fed has recently targeted the fed funds rate, it may choose to target a different short-term rate in the future, as the fed funds rate reflects only a small and perhaps unrepresentative subset of money market transactions.

Yellen (2016) describes changes in the Fed’s monetary toolkit over time, indicating that the central bank will retain the option of using asset-purchases and aggressive forward guidance to combat recessions. Many analysts forecast a relatively low-growth, low-inflation environment

80 The BOE has ended FLS drawdowns, raised its deposit and policy rates and provided bearish forward guidance. The ECB reduced new asset purchases twice in 2018 and says that it will end them in December 2018.
that will constrain the use of conventional policy tools and make the retention of contingent UMP a necessity. Reifschneider (2016) assesses that a combination of conventional tools, asset purchases and forward guidance will be adequate to compensate for most negative shocks.

Why are central banks returning to conventional, short-term interest rate management rather than continuing to use UMP? UMP is unconventional because it requires central banks to do unusual things, such as manipulate the maturity structure of the national debt, which is usually a Treasury responsibility, or set negative rates on bank deposits with the central bank. These measures are unusual because they impose costs, which could include having the central bank and the Treasury work at cross-purposes with the structure of government debt. In addition, particular central banks have difficulties with specific policies. For example, the international nature of the Eurosystem makes broad-based asset purchases more complex for the ECB than for the Fed or BOE because the ECB must choose how much to buy from many fragmented, national bond markets.

These costs suggest to us that central banks are making the correct decision to return to conventional monetary policy as the default. When financial markets are functioning well and short-term interest rates are positive, central banks should use conventional short-term interest rate tools and reserve UMP for times of unusual financial market stress and/or non-positive short rates.

Recommending directions for future research is difficult because it is subject to an efficient markets problem of sorts. If a research agenda were obviously valuable and relatively straightforward, it would already have been done. With that caveat, we believe that it would be valuable to focus future theoretical research on the nature of the fundamental problem with financial crises and the ELB. What is the underlying failure that produces suboptimal outcomes and how should one model it? How does UMP mitigate the consequences of this failure? The theoretical modeling could better connect with empirics, as well. That is, researchers might develop general equilibrium models of some of the channels identified in the empirical event-study literature. Macro models of UMP would benefit from more sophisticated financial sectors and portfolio choice problems that rationalize the local supply and duration effects that we see in the data.

With respect to practical suggestions for empirical work, we believe that the trend toward inquiries with detailed micro data on mortgages, credit, and banks has proven very valuable, as has the trend to looking at the covariances of multiple assets with monetary shocks. There is also scope for more empirical research on state-dependent macro effects of UMP.
References


Cahn, Christophe, Julien Matheron, and Jean-Guillaume Sahuc. Forthcoming. “Assessing the Macroeconomic Effects of LTROs during the Great Recession.” Journal of Money, Credit and Banking.


Harrison, Richard. 2012, “Asset purchase policy at the ELB for interest rates.”


117


Figure 1: Assets and Liabilities of the Bank of Japan: 1999-2006

SOURCE: Bank of Japan
Figure 2: Assets and Liabilities of the Federal Reserve: 2008-2018

SOURCE: Federal Reserve
Figure 3: Assets and Liabilities of the Bank of England: 2008-2018

SOURCE: Bank of England
Figure 4: Assets and Liabilities of the European Central Bank: 2008-2018

SOURCE: European Central Bank
NOTE: “Lending to Euro Area Credit Institutions” contains Lending to Euro Area Credit Institutions in Euro and Other Claims on Credit Institutions in Euro. “FX Reserves” Contains Claims on Euro Area and non-Euro Area Residents in Foreign currency. “Other Assets” contains Gold and Gold Receivables, Claims on non-Euro Area Residents in Euro, General Government Debt, and Other Assets. “Central Bank Reserves” contains Liabilities to Euro-Area Credit Institutions in Euro. “Other Liabilities” contains Debt Certificates Issued, Euro-denominated Liabilities to Other Euro Area Residents and non-Euro Area Residents, Foreign Currency Liabilities, Counterparts of SDRs allocated by the IMF, Revaluation Accounts, Capital and Reserves, and Other Liabilities. ABSPP, Asset-Backed Securities Purchase Program; APP, Asset Purchase Program; CBPP, Covered Bond Purchase Program; CSPP, Corporate Sector Purchase Program; EA, euro area; FRFA, Fixed-Rate Procedure with Full Allotment; MRO, Main Refinancing Operations; LTRO, Longer-Term Refinancing Operations; OMT, Outright Monetary Transactions; PSPP, Public Sector Purchase Program; SMP, Securities Markets Program; TLTRO, Targeted Longer-Term Refinancing Operations.
Figure 5: Assets and Liabilities of the Bank of Japan: 2008-2018

SOURCE: Bank of Japan
Figure 6: Major Central Bank Policy Rates: 2005-2018

NOTE: The key policy rates for the BOE, Fed, ECB, and BOJ are, respectively, the Official Bank Rate, the Federal Funds Target Rate, the Main Refinancing Operations Rate, and the Uncollateralized Overnight Call Rate. Between April 2013 and February 2016, the BOJ did not set a target for the uncollateralized overnight call rate. Starting in March 2016, the BOJ resumed targeting a short-term interest rate, for which we report the BOJ’s basic balance rate.
Figure 7: Major Central Bank Deposit Rates: 2005-2018

NOTE: For the BOE, we plot the Official Bank Rate. For the ECB, we plot the Deposit Facility Rate. For the Fed, we plot the interest rate on excess reserves. For the BOJ we plot the Uncollateralized Overnight Call Rate Lower Limit (2005- April 2013) and the Deposit Facility Policy Rate (February 2016-present). Between April 2013 and February 2016, the BOJ did not set a target deposit rate.
Figure 8: High-frequency nominal futures price movements on March 18, 2009

NOTE: The figure shows the high-frequency movements of local currency international bond futures prices (top panel), spot exchange rates (center panel) and S&P 500 and NY light crude futures (bottom panel) around the FOMC release (vertical line) on March 18, 2009. The x-axis values denote hours from midnight, U.S. Eastern Time, of the day of the announcement, and the vertical line denotes the time of the announcement. The figure is excerpted from the appendix of Neely (2015).
Figure 9: Systematic forecast errors for the fed funds rate, 2008-2018 (fed funds futures at different points in time)

SOURCE: FRB, Bloomberg Finance LP, DB Global Research.
NOTE: Data for the graph courtesy of Torsten Slok, Deutsche Bank.
Figure 10: High frequency asset price movements on June 19, 2013

NOTE: The top and bottom panels show U.S. 10-year bond yields and the foreign exchange value of the dollar near the FOMC meeting and press conference of June 19, 2013. The dashed vertical lines denote 2:15 pm EST, on June 19, 2013. CAD, Canadian dollar; EUR, euro; GBP, British pound; JPY, Japanese yen; USD, U.S. dollar. Missing values reflect no reported trading. The figure is excerpted from Neely (2014).
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></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>
</tr>
<tr>
<td>Safety premium</td>
<td>X</td>
<td>X (high-grade only)</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: The impact of QE1 events on yields (in basis points), as excerpted from Table 1 of Gagnon et al. (2011)

<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(^b)</th>
<th>Ten-Year Term Premium</th>
<th>Ten-Year Swap</th>
<th>Baa Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/1/2008</td>
<td>Chairman speech</td>
<td>-8</td>
<td>-19</td>
<td>-39</td>
<td>-15</td>
<td>-17</td>
<td>-17</td>
<td>-12</td>
</tr>
<tr>
<td>12/16/2008</td>
<td>FOMC statement</td>
<td>-9</td>
<td>-26</td>
<td>-29</td>
<td>-37</td>
<td>-12</td>
<td>-32</td>
<td>-11</td>
</tr>
<tr>
<td>1/28/2009</td>
<td>FOMC statement</td>
<td>10</td>
<td>14</td>
<td>14</td>
<td>11</td>
<td>9</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>4/29/2009</td>
<td>FOMC statement</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>-3</td>
</tr>
<tr>
<td>6/24/2009</td>
<td>FOMC statement</td>
<td>10</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8/12/2009</td>
<td>FOMC statement</td>
<td>-2</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9/23/2009</td>
<td>FOMC statement</td>
<td>1</td>
<td>-3</td>
<td>-3</td>
<td>-1</td>
<td>-1</td>
<td>-5</td>
<td>-4</td>
</tr>
<tr>
<td>11/4/2009</td>
<td>FOMC statement</td>
<td>-2</td>
<td>6</td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>12/16/2009</td>
<td>FOMC statement</td>
<td>-2</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>1</td>
<td>-1</td>
</tr>
<tr>
<td>1/27/2010</td>
<td>FOMC statement</td>
<td>11</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3/16/2010</td>
<td>FOMC statement</td>
<td>-3</td>
<td>-5</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
<td>-5</td>
</tr>
<tr>
<td>1/6/2009</td>
<td>Minutes release</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>-17</td>
<td>-1</td>
<td>-9</td>
<td>-14</td>
</tr>
<tr>
<td>2/18/2009</td>
<td>Minutes release</td>
<td>9</td>
<td>11</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>4/8/2009</td>
<td>Minutes release</td>
<td>2</td>
<td>-4</td>
<td>-7</td>
<td>-9</td>
<td>-4</td>
<td>-6</td>
<td>-6</td>
</tr>
<tr>
<td>5/20/2009</td>
<td>Minutes release</td>
<td>-5</td>
<td>-5</td>
<td>-5</td>
<td>-7</td>
<td>-4</td>
<td>-4</td>
<td>-10</td>
</tr>
<tr>
<td>7/15/2009</td>
<td>Minutes release</td>
<td>7</td>
<td>13</td>
<td>16</td>
<td>16</td>
<td>10</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>9/2/2009</td>
<td>Minutes release</td>
<td>-1</td>
<td>-6</td>
<td>-6</td>
<td>-4</td>
<td>-7</td>
<td>-8</td>
<td>-5</td>
</tr>
<tr>
<td>10/14/2009</td>
<td>Minutes release</td>
<td>1</td>
<td>7</td>
<td>10</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>11/24/2009</td>
<td>Minutes release</td>
<td>0</td>
<td>-5</td>
<td>-5</td>
<td>-9</td>
<td>-5</td>
<td>-6</td>
<td>-3</td>
</tr>
<tr>
<td>1/6/2010</td>
<td>Minutes release</td>
<td>-2</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>-1</td>
</tr>
<tr>
<td>2/17/2010</td>
<td>Minutes release</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</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

NOTE: The title to this table in Gagnon et al. (2011) is “Table 1: Interest Rate Changes around Baseline and Extended Event Set Announcements.”
SOURCES: Bloomberg L.P.; Barclay’s Capital; Board of Governors of the Federal Reserve System.

\(^a\) Included in the baseline event set.
\(^b\) Two-day change for agency mortgage-backed securities on March 18, 2009, because of a Bloomberg L.P. data error.