ECONOMIC RESEARCH
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# An Analysis of the Literature on International Unconventional Monetary Policy

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| **Authors** | Saroj Bhattarai, and Christopher J. Neely |
| **Working Paper Number** | 2016-021E |
| **Revision Date** | May 2020 |
| **Citable Link** | https://doi.org/10.20955/wp.2016.021 |
| **Suggested Citation** | Bhattarai, S., Neely, C.J., 2020; An Analysis of the Literature on International Unconventional Monetary Policy, Federal Reserve Bank of St. Louis Working Paper 2016-021. URL https://doi.org/10.20955/wp.2016.021 |

# An Analysis of the Literature on International Unconventional Monetary Policy

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August 30, 2020

**Abstract:** This paper evaluates the literature on international unconventional monetary policies (UMP). Introducing market segmentation, limits-to-arbitrage, and time-consistent policy in standard models permits a theoretical role for UMP. Empirical studies provide compelling evidence that UMP influenced international asset prices and tail-risk in the desired manner. Calibrated modeling and vector autoregressive (VAR) exercises imply that these policies also improved macroeconomic outcomes. We assess the recent debate on the empirical evidence and discuss central bank assessments of UMP. Despite qualified successes, we recommend that UMP be reserved for crises and/or 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

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Table of Contents


1 Introduction ........................................................................................................ 1
2 Theoretical frameworks ........................................................................................ 5
2.1 Ineffectiveness of quantitative easing ................................................................ 5
2.2 Models of effective quantitative easing ............................................................ 13
2.3 Other unconventional monetary policy .............................................................. 21
3 The modern practice of unconventional monetary policy ...................................... 23
4 The effects of unconventional monetary policy on asset markets .......................... 27
4.1 Event study methodology ................................................................................ 27
4.2 Methods to assess channels of unconventional monetary policy ......................... 29
4.3 The BOJ's early (1999-2006) quantitative easing and forward guidance policies ........ 31
4.4 Forward guidance ........................................................................................... 32
4.5 Broad asset purchase and forward guidance effects on asset prices ..................... 33
4.6 Channels of broad asset purchase and forward guidance effects on asset prices .......... 38
4.7 Broad asset purchase and forward guidance effects on loans and portfolio choice....... 42
4.8 How did narrow asset purchases affect asset prices, volatility and capital flows?........ 44
4.9 How did support programs affect the banking system? ........................................ 45
4.10 Negative interest rates .................................................................................. 46
5 Macroeconomic effects of unconventional policies .............................................. 48
5.1 Methods to study macroeconomic effects of unconventional monetary policy ............ 49
5.2 What are the empirical macroeconomic effects of unconventional monetary policy?.. 49
6 Evaluations of unconventional monetary policy ................................................... 55
6.1 Skepticism on the effects of broad asset purchases and forward guidance ................... 55
6.2 Central bank evaluations of unconventional monetary policy ................................ 58
7 Discussion and conclusion .................................................................................. 59
8 References ........................................................................................................ 63

# 1 Introduction

- "Well, the problem with QE is it works in practice, but it doesn't work in theory." — 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 engage in emergency lending and reduce short-term rates to near zero to stabilize their financial and real sectors.[1] With the zero lower bound (ZLB) inhibiting conventional policy, central banks would employ a variety of unconventional monetary policy (UMP) to stimulate their economies.[2] The most important of these have been broad asset purchases, i.e., quantitative easing (QE), and communication with the public, i.e., forward guidance (FG), to reduce medium- and long-term interest rates. Central banks would also institute negative deposit rates to encourage banks to shift toward higher-yielding assets and narrow asset purchases to improve functioning in specific markets. 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 Swedish Central Bank (Riksbank), and the Danish National Bank (DNB) have employed UMP.

Although central banks have tried to revert to more conventional policies, the natural rate of interest has declined to a low level and such a decline in natural rates leads to lower policy rates, which means that the zero lower bound (ZLB) on interest rates can limit conventional monetary policy responses to downturns (Laubach and Williams 2016).[3] Discretionary fiscal policy is an option but is considered to be slower and less flexible.[4] Therefore, in an era of low inflation, low growth, and low interest rates, UMP will likely remain an important contingency tool. Policymakers have recognized the value of UMP.

- "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." — Stanley Fischer (Fischer 2016)

Given that central banks will retain UMPs as essential instruments for ZLB events,

[1] The Federal Reserve and Bank of England reduced their policy rates to near zero in 2008-2009, although euro-area policy rates did not near zero until 2013-2014. Bank of Japan policy rates have not been much above zero since 1995.

[2] Emergency lending is of a shorter duration and narrowly focused on a particular firm or market segment while monetary policy widely and persistently influences interest rates and the overall availability of credit. There is no bright line between monetary and lending tools, however.

[3] This paper uses both terms, effective lower bound (ELB) and zero lower bound (ZLB), depending on the context.

[4] Automatic fiscal stabilizers function quickly but are generally thought to be insufficient, by themselves, for full macro stabilization.

economists and financial market participants should understand how they affect financial markets and the broader economy. Our paper lays out the theory of UMP and selectively synthesizes and evaluates the sizable and growing empirical literature on the topic. We review the theories of UMP and the modern practice of UMP before describing the literature's assessment of the effects of such polices on financial markets and the macro economy.

We review the theory of UMP with a unified and self-contained stochastic-discount factor framework to show why QE is irrelevant in a standard general equilibrium model and then extend that model to provide a rationale for UMP. In particular, policy commitment renders the maturity composition of government debt or central bank assets irrelevant in the model, even when Ricardian equivalence fails. We then show how frictions such as participation constraints, leverage constraints that limit arbitrage, and signaling effects under time-consistent/no-commitment policy introduce a role for QE. We follow with theoretical frameworks that rationalize the use of FG and negative interest rate policies (NIRP).

UMP effects on financial markets depend on the type of policy, details of program execution and economic conditions. For example, the Fed's choice of assets to purchase (i.e., Treasuries vs. mortgage-backed securities (MBS)) differentially affected bank lending and mortgage rates. Policy effects are also state dependent. The initial Fed asset purchases, for example, influenced international portfolio flows differently than did similar later policies, presumably because risk tolerance was higher during later programs.

FG and QE have been the most important UMP, used by all four major central banks: The Fed, the BOE, the ECB and the BOJ. Researchers have often studied FG and QE jointly because the policies were often coincident, and their effects are difficult to disentangle. The forward-looking nature of financial markets allowed event studies to be particularly useful in studying UMP, although other methods have provided similar inference. Large long-bond purchases and accompanying FG strongly influenced yields through local supply, duration, and signaling channels. Such purchases also reduced tail risk and the value of the domestic currency and raised break-even inflation and stock prices, although the latter effects were not as strong as one might hope. The type of bond purchased mattered in several dimensions, including for bank lending. Bond purchases also influenced quantities of loans and portfolio shares. Asset purchases prompted financial institutions to rebalance their portfolios toward higher-yielding bonds and corporations to issue more bonds.

Early Fed and BOE asset purchase programs provide the best estimates for the effects of QE and FG: The Fed's QE1 program (about 12 percent of U.S. 2009 GDP) reduced 10-year Treasury yields by 55 to 91 basis points (b.p.), depending on the event set, with greater effects on riskier assets (Gagnon et al. 2011) and substantial effects on the yields of other advanced countries

(Neely 2015).[5] The similarly sized BOE QE1 program had similarly sized effects on domestic yields (Joyce, Tong, and Woods 2011). Low-frequency quantity-of-debt studies estimate yield effects near the lower end of the 55 to 91 b.p. range (Ihrig et al. 2018). Some studies of the ECB's January 2015 asset purchase program show purchase/GDP-scaled point estimates of 33 to 55 b.p. in 10-year yield reductions, with larger effects for riskier debt (Altavilla, Carboni, and Motto 2015). While these estimates are at the low end or below the 55-91 b.p. range for the Fed-BOE, other studies' point estimates are nearer the higher end of the Fed-BOE range (De Santis 2020). While point estimates vary with procedures to some extent, studies provide basically consistent inference across cases and methods.

While broad asset purchases reduced yields across the board, the ECB initially employed more targeted purchases to improve market functioning or reduce specific rates. These purchases generally reduced the targeted yield or spread and often spilled over to related markets.

The BOE, the BOJ, and the ECB supplemented their asset purchase programs with novel 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.

In another fresh approach, the ECB, the BOJ, and several smaller central banks set negative deposit rates on reserves. These negative rates had a modest expansionary impact and generally did not pass through to retail deposit rates. Evidence is mixed on whether negative deposit rates reduced the profitability of some financial firms. If so, the effects seem to have been limited.

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 asset purchases and FG with dynamic stochastic general equilibrium (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. Other empirical researchers have used SVARs with various identification strategies 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.

Despite evidence of significant successes, the UMP programs have also had some unintended consequences. 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 that helped to recapitalize banks by boosting bond prices appears to have prompted inappropriate lending to low-quality borrowers and negative knock-on effects in the borrowers' industries. Similarly, the BOE's incentive schemes to boost domestic bank

[5] One should be cautious about casual reference to such yield estimates as the effects doubtless come from a combination of FG and QE and depend on the size and term structure of outstanding debt, international substitutability, shape of the yield curve, and state of the economy.

lending may have skewed incentives and unintentionally reduced international lending.

While researchers were investigating the effects of UMP, central bankers were evaluating international monetary policies. Broadly speaking, central bankers see clear evidence that asset purchase programs and other UMP influenced asset prices and portfolio choices in the desired direction and judge that such changes have very likely produced the desired effects on the macro economy. Nevertheless, central bankers also readily acknowledge that UMP is not a panacea, but 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.[6]

Despite the apparent successes of UMP, serious questions remain, particularly about the effects of the broad asset purchase programs. Many economists have argued that the effects of asset purchases and FG are much smaller than commonly understood, or that such effects are transient or that later programs had much smaller effects than earlier programs. While we agree that sampling variation and methodological uncertainty produce substantial uncertainty about the effects of UMP, we interpret the evidence from the literature to indicate that QE and FG substantially changed asset prices for many months or years and that later programs had effects similar to the initial purchases. Such new tools have successfully stimulated international economies when the ELB constrained short interest rates.

Although we believe that UMP has been broadly—if moderately—successful, practical difficulties with these tools remain. For example, central bank purchases of long-term bonds can work at cross purposes with Treasury efforts to manage national debt effectively, raising the delicate issue of whether coordination between the central bank and Treasury is desirable. Similarly, negative interest rates can create particular problems for financial firms. Because UMP is useful at the ELB but can create problems and distortions, we recommend that central banks normally conduct monetary policy by conventional management of short rates and reserve UMP for times when interest rates near the lower bound and/or financial markets require special intervention.

Section 2 reviews the theory of various 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 characterizes research on UMP effects on financial markets, while Section 5 documents its effects on the macro economy. Section 6 presents skeptical views on the value of asset purchases and FG, as well as the views of central bankers. Section 7 summarizes and outlines our views on future policy and research.

[6] The Fed and ECB have also had some difficulty maintaining inflation at desired levels. From 2010 through 2019, the arithmetic average of 12-month PCE, HICP and CPI inflation for the U.S., the euro area, and Japan were 1.54, 1.35, and 0.47 percent, respectively.

## 2 Theoretical frameworks

To explain the theory of UMP effects, we will consider a general equilibrium stochastic discount factor (SDF) framework that can be applied to heterogeneous policies, i.e., broad and narrow asset purchases, bank lending support programs, FG, and NIRP. As UMP is most often associated with QE, we will first explain why QE has no effect in standard models before extending the framework to rationalize QE. We finish with rationales for FG and NIRP.

QE has no effect on prices or output in standard general equilibrium macroeconomic models. Consider a canonical asset pricing condition

$$\mathbb{E}_t[\Lambda_{t,t+1}(R_{L,t+1} - R_{t+1})] = 0, \qquad (1)$$

where $\mathbb{E}_t$ is the expectation operator conditional on period-$t$ information, $\Lambda_{t,t+1}$ is the SDF, $R_{L,t+1}$ is the real return on long-term bonds (or capital), and $R_{t+1}$ is the real return on short-term bonds, where the nominal short-term return is the conventional monetary policy instrument. Equation (1) holds generally, as long as there are no arbitrage opportunities.[7] In standard macroeconomic models, (1) simply residually determines $R_{L,t+1}$, the return on long-term bonds, as $R_{t+1}$, the short-term rate, and the rest of the macroeconomic equilibrium are determined independently of (1). Then, QE can affect long yields and activity only through the signaling channel, in which *current* purchases affect the government's choice of the short-term rate in the *future*. For other channels to work, this no-arbitrage condition must be modified with either market participation constraints or limits to arbitrage. We now detail these claims.

### 2.1 Ineffectiveness of quantitative easing

Wallace (1981) showed that a Modigliani-Miller theorem applies to central bank balance sheet policies, rendering them irrelevant in a class of models. Lucas and Stokey (1983) showed that even with distortionary taxes, under credible commitment, only the stock of government debt matters for equilibrium, and the maturity composition of debt is irrelevant. We undertake similar analyses here while incorporating model features from the recent literature and characteristics of actual central bank policies.

We now present a general equilibrium monetary model in which QE is neutral.

***Private sector:*** A representative household maximizes expected lifetime utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [U(c_t, h_t) + W(m_t)], \qquad (2)$$

where $\beta \in (0,1)$ is the discount factor, $c_t$ is consumption, $h_t$ is hours supplied, and $m_t$ is real money balances. $\mathbb{E}_0$ is the expectation operator conditional on period-0 information. The flow utility $U(c_t, h_t)$ is strictly increasing and concave in $c_t$ and strictly decreasing and concave in $h_t$.

[7] Equation (1) is often called a "no-arbitrage condition" for that reason. (1) does not require complete markets. As long as the two bonds are tradable, (1) will hold in the absence of participation constraints or limits to arbitrage.

The flow utility from real balances $W(m_t)$ is strictly increasing and concave to a (finite) satiation level $m^*$, with no marginal utility of real balances above $m^*$. That is, $W_m > 0, W_{mm} < 0$ when $m_t < m^*$, while $W_m = 0$ when $m_t \geq m^*$.

The household's flow budget constraint (in real terms) is given by

$$Q_{1,t}b_{1,t}^H + Q_{2,t}b_{2,t}^H + Q_{1,t}l_{1,t}^H + c_t + m_t - w_t h_t - \varphi_t + \Upsilon_t =$$
$$\left[b_{1,t-1}^H + Q_{1,t}b_{2,t-1}^H + l_{1,t-1}^H + m_{t-1}\right]\Pi_t^{-1}, \quad (3)$$

where $b_{1,t}^H = \frac{B_{1,t}^H}{P_t}$ with $B_{1,t}^H$ the nominal one-period Treasury bond held by the household and $P_t$ the aggregate price level; $b_{2,t}^H = \frac{B_{2,t}^H}{P_t}$ with $B_{2,t}^H$ the nominal two-period Treasury bond held by the household; $l_{1,t}^H = \frac{L_{1,t}^H}{P_t}$ with $L_{1,t}^H$ the nominal one-period central bank reserves held by the household; and $m_t = \frac{M_t}{P_t}$ with $M_t$ the nominal stock of money.[8] Moreover, $\Pi_t = \frac{P_t}{P_{t-1}}$ is gross inflation, $Q_{1,t}$ is the price of the one-period government bond and central bank reserves, $Q_{2,t}$ is the price of the two-period government bond, $w_t$ is real wages, $\varphi_t$ is firm profits, and $\Upsilon_t$ is lump-sum taxes paid to the Treasury.

The household chooses $\{c_t, h_t, m_t, b_{1,t}^H, b_{2,t}^H, l_{1,t}^H\}_{t=0}^{\infty}$ to maximize (2), subject to a sequence of budget constraints (3) and a no-Ponzi-game borrowing limit, while taking as given initial wealth and $\{\Pi_t, \varphi_t, w_t, Q_{1,t}, Q_{2,t}, \Upsilon_t\}_{t=0}^{\infty}$.

The consumption good $c_t$ is an aggregate of a continuum of differentiated varieties indexed by $i \in [0,1]$, $c_t = \left[\int_0^1 c_t(i)^{\frac{\nu-1}{\nu}} di\right]^{\frac{\nu}{\nu-1}}$. Here, $\nu > 1$ is the elasticity of substitution among the varieties. Monopolistically competitive firms produce these varieties and are indexed by $i \in [0,1]$. Firm $i$ produces output $y_t(i)$ with labor $h_t(i)$ as input:

$$y_t(i) = A_t F(h_t(i)), \quad (4)$$

where the production function $F(h_t(i))$ is strictly increasing and concave in $h_t(i)$ and $A_t$ is a stationary aggregate productivity shock. Firms hire labor in a common, competitive market.

Firm $i$ sets price $P_t(i)$ for its variety subject to a cost, $d(P_t(i)/P_{t-1}(i))$, of adjusting prices, where $d(.) = \frac{\kappa}{2}\left(\frac{P_t(i)}{P_{t-1}(i)} - 1\right)^2$.[9] The demand function for variety $i$, derived from a standard static expenditure minimization problem of the household, is given by

[8] The one-period Treasury bond and the one-period central bank reserves are perfect substitutes.

[9] While prices always adjust here, the usual "flexible price" case occurs as the limit when $\kappa = 0$.

$$\frac{y_t(i)}{y_t} = \left(\frac{P_t(i)}{P_t}\right)^{-\nu}, \tag{5}$$

where $y_t$ is aggregate output.[10] Firms maximize expected discounted profits:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \varphi_t(i), \tag{6}$$

where $\Lambda_{0,t} \equiv \beta^t \frac{U_c(c_t,h_t)}{U_c(c_0,h_0)}$ is the SDF and $\varphi_t(i) \equiv \frac{P_t(i)}{P_t} y_t(i) - d\left(\frac{P_t(i)}{P_{t-1}(i)}\right) - w_t h_t(i)$ is profits.

Firm $i$ chooses $\{y_t(i), h_t(i), P_t(i)\}_{t=0}^{\infty}$ to maximize (6) subject to a sequence of production functions (4) and demand functions (5), while taking as given $\{P_t, y_t, \Lambda_{0,t}, w_t\}_{t=0}^{\infty}$. As is standard, we consider a symmetric equilibrium across firms.

***Government:*** We now describe the balance sheets of the government and define the appropriate conventional and unconventional policy instruments. The central bank flow budget constraint is

$$Q_{1,t} b_{1,t}^C + Q_{2,t} b_{2,t}^C - Q_{1,t} l_{1,t}^C + T_t = b_{1,t-1}^C \Pi_t^{-1} + Q_{1,t} b_{2,t-1}^C \Pi_t^{-1} - l_{1,t-1}^C \Pi_t^{-1} + s_t, \tag{7}$$

where $b_{1,t}^C = \frac{B_{1,t}^C}{P_t}$ with $B_{1,t}^C$ the nominal one-period Treasury bond held by the central bank and $b_{2,t}^C = \frac{B_{2,t}^C}{P_t}$ with $B_{2,t}^C$ the nominal two-period Treasury bond held by the central bank. Moreover, the central bank also issues nominal one-period liabilities, $L_{1,t}^C$, which are interest-bearing reserves. These were the primary liabilities issued by central banks during the QE period. Thus, $l_{1,t}^C = \frac{L_{1,t}^C}{P_t}$. The term $s_t \equiv m_t - m_{t-1}\Pi_t^{-1}$ represents seigniorage, which results from the central bank issuing the non-interest-bearing liabilities (i.e., fiat money, $m_t$), while $T_t$ is the central bank transfer to the Treasury. $N_{-1}^C > 0$ is the initial nominal net asset position of the central bank.

There are two types of monetary policy. Conventional monetary policy changes the short-term interest rate, $Q_{1,t}^{-1}$, while UMP changes the *central bank balance sheet composition*. As given in (7), we first denote the net asset position of the central bank's balance sheet by $b_t^C \equiv Q_{1,t} b_{1,t}^C + Q_{2,t} b_{2,t}^C - Q_{1,t} l_{1,t}^C$. We now formally define the UMP instrument as the proportion of the two-period asset in the central bank's asset position, denoted by $b_{R,t}^C$,

$$b_{R,t}^C \equiv \frac{Q_{2,t} b_{2,t}^C}{Q_{1,t} b_{1,t}^C + Q_{2,t} b_{2,t}^C - Q_{1,t} l_{1,t}^C} = \frac{Q_{2,t} b_{2,t}^C}{b_t^C}.$$

$b_{R,t}^C$ thus reflects maturity mismatch in the central bank balance sheet. If $b_{R,t}^C$ were zero, then both the assets and liabilities would have the same maturity.

QE policy *changes $b_{R,t}^C$, while keeping $b_t^C$ constant*. Thus, when the central bank issues one-

[10] The static expenditure minimization problem implies $P_t = \left[\int_0^1 p_t(i)^{1-\nu} di\right]^{\frac{1}{1-\nu}}$ and $P_t c_t = \int_0^1 p_t(i) c_t(i) di$.

period reserves $l^C_{1,t}$ to finance the purchase of two-period bonds $b^C_{2,t}$, $b^C_{R,t}$ *increases* but $b^C_t$ *does not change*.[11] Such a policy can affect transfers to the Treasury, $T_t$ through (7).[12]

For simplicity, we assume that the Treasury does not spend and keeps a constant supply of Treasury bonds. The Treasury flow budget constraint is

$$T_t + \Upsilon_t + Q_{1,t} b^T_{1,t} + Q_{2,t} b^T_{2,t} = b^T_{1,t-1}\Pi_t^{-1} + Q_{1,t} b^T_{2,t-1}\Pi_t^{-1}, \tag{8}$$

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. We can impose the Treasury's debt policy on (8)

$$b^T_{1,t} = b^T_1, \quad b^T_{2,t} = b^T_2. \tag{9}$$

Let $N^T_{-1} > 0$ be the initial nominal debt position of the Treasury.

To interpret QE from the perspective of a "consolidated" government, we combine the two budget constraints (7)-(8) to obtain a consolidated government flow constraint

$$Q_{1,t} b_{1,t} + Q_{2,t} b_{2,t} + \Upsilon_t + s_t = b_{1,t-1}\Pi_t^{-1} + Q_{1,t} b_{2,t-1}\Pi_t^{-1}, \tag{10}$$

where $T_t$, central bank transfers to the Treasury, drop out and the relevant government debt positions are those held by the public. That is, $b_{1,t} = b^H_{1,t} + l^H_{1,t}$, $b_{2,t} = b^H_{2,t}$, $b_{1,t-1} = b^H_{1,t-1} + l^H_{1,t-1}$, and $b_{2,t-1} = b^H_{2,t-1}$ are household holdings of one- and two-period government debt.[13] Let $N_{-1} \equiv N^T_{-1} - N^C_{-1} > 0$ be the initial nominal liability of the consolidated government.

As before, let us denote the level/stock of government debt by $b_t \equiv Q_{1,t} b_{1,t} + Q_{2,t} b_{2,t}$, and the proportion of long-maturity government debt by

$$b_{R,t} \equiv \frac{Q_{2,t} b_{2,t}}{Q_{1,t} b_{1,t} + Q_{2,t} b_{2,t}} = \frac{Q_{2,t} b_{2,t}}{b_t}.$$

QE *changes* $b_{R,t}$ while keeping $b_t$ *constant*. Thus, as the central bank increases its long-term bond holdings (raising $b^C_{R,t}$), it reduces the ratio of long-term government debt held by the public (reducing $b_{R,t}$). Such a policy can affect the dynamics of taxes, $\Upsilon_t$, through (10).

***No role for QE:*** We now establish why QE policy does not affect prices and quantities under common formulations of conventional monetary policy. The aggregate private sector equilibrium

[11] If the central bank issues one-period reserves $l^C_{1,t}$ to buy one-period assets $b^C_{1,t}$, then there is no change in *either* $b^C_{R,t}$ or $b^C_t$. We define QE as changing the composition of the central bank balance sheet, keeping net position constant. A "broader" QE definition might include a change in net position such as an expansion of interest-bearing liabilities $l^C_{1,t}$ that leads to a decrease in $b^C_t$ and an increase in $T_t$. This is close to traditional debt policy and we do not consider it to be QE. Another even broader policy, sometimes called "pure" QE, could be an expansion of non-interest-bearing central bank liabilities, $m_t$ , also implemented through changes in $T_t$. We discuss such policy later.

[12] As we discuss later, a key question is whether $b^C_{R,t}$ affects $T_t$ independently of $b^C_t$.

[13] Deriving (10) uses the market-clearing conditions $b^H_{1,t} + b^C_{1,t} = b^T_{1,t} = b^T_1$, $b^H_{2,t} + b^C_{2,t} = b^T_{2,t} = b^T_2$, and $l^H_{1,t} = l^C_{1,t}$.

conditions and resource constraints are given by

$$\frac{U_c(c_t,h_t)}{W_m(m_t)} = \frac{1}{1-Q_{1,t}}, \tag{11}$$

$$Q_{1,t}^{-1} \geq 1, \tag{12}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\frac{\Pi_{t+1}^{-1}}{Q_{1,t}}\right] = 1, \tag{13}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\left(\frac{Q_{1,t+1}\Pi_{t+1}^{-1}}{Q_{2,t}} - \frac{\Pi_{t+1}^{-1}}{Q_{1,t}}\right)\right] = 0, \tag{14}$$

$$\left[\left(\frac{\nu-1}{\nu}\right) + \frac{U_h(c_t,h_t)}{U_c(c_t,h_t)}\frac{1}{A_tF_h(h_t)}\right]\nu y_t + \kappa(\Pi_t - 1)\Pi_t = \kappa\mathbb{E}_t\left[\Lambda_{t,t+1}(\Pi_{t+1} - 1)\Pi_{t+1}\right], \tag{15}$$

$$y_t = A_tF(h_t) = c_t + \frac{\kappa}{2}(\Pi_t - 1)^2. \tag{16}$$

(11) implies that the ZLB on the short-term policy rate, (12), binds, i.e., $Q_{1,t}^{-1} = 1$, when $W_m(m_t) = 0$ or $m_t \geq m^*$.[14] Thus, short-term interest rates reach the ZLB when real balances reach the satiation level, $m^*$.[15] We note that (14) provides a consumption-based formulation for the SDF, with $\Lambda_{t,t+1} \equiv \beta\frac{U_c(c_{t+1},h_{t+1})}{U_c(c_t,h_t)}$, which is a special case of (1). Moreover, one- and two-period real bond returns are $R_{t+1} \equiv \frac{\Pi_{t+1}^{-1}}{Q_{1,t}}$ and $R_{2,t+1} \equiv \frac{Q_{1,t+1}\Pi_{t+1}^{-1}}{Q_{2,t}}$, respectively.

Next, we can show the irrelevance of QE in this economy, under common formulations of conventional monetary policy, using arguments like those in Eggertsson and Woodford (2003) and Cúrdia and Woodford (2011). First, consider a simple feedback rule that determines the central bank's short-term interest rate policy

$$\beta Q_{1,t}^{-1} = \left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}, \tag{17}$$

where $\phi_\pi \geq 1$ is the feedback parameter and $\Pi$ is the steady-state value of inflation.[16] Then, (13), (15), (16), and (17), subject to (12), completely determine the equilibrium path of $\{\Pi_t, Q_{1,t}, c_t, h_t\}_{t=0}^{\infty}$. Thus, neither the maturity composition of the central bank's balance sheet ($b_{R,t}^C$) nor the maturity composition of outstanding government debt ($b_{R,t}$) have a role in

[14] A large enough shock that makes the "natural rate of interest" (i.e., the interest rate in an economy without sticky prices) negative makes the ZLB bind in standard models. In the set-up here, the natural rate of interest is a function of expected change in the technology $A_t$. Thus, a ZLB can bind if agents expect future technology to be sufficiently lower than present. Discount shocks, i.e., a stochastic $\beta$, can also induce a binding ZLB.

[15] In addition to the first-order necessary conditions above, optimality requires a transversality condition. The optimality conditions above have the usual interpretation. (11) is a money demand equation that equates the marginal rate of substitution between consumption and real balances with the opportunity cost of holding money; (13) is a standard Euler equation; (14) determines the price of the two-period bond; and (15) is a Phillips curve. Finally, (16) is the aggregate resource constraint with adjustment costs.

[16] The restriction $\phi_\pi \geq 1$ ensures that the rule satisfies the Taylor principle.

determining equilibrium.[17] The no-arbitrage condition, (14), determines the two-period bond price, $\{Q_{2,t}\}_{t=0}^{\infty}$ and the money demand condition, (11), determines money balances $\{m_t\}_{t=0}^{\infty}$.

The ineffectiveness result holds even if conventional monetary policy is optimal under commitment, i.e., it is Ramsey monetary policy. Then, the central bank chooses a contingent path for its instrument $\{Q_{1,t}^{-1}\}_{t=0}^{\infty}$ in period 0 to maximize household welfare

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [U(c_t, h_t) + W(m_t)],$$

subject to the constraints (11), (12), (13), (15), and (16). The first-order conditions of this maximization problem, together with the constraints, determine $\{\Pi_t, Q_{1,t}, c_t, h_t, m_t\}_{t=0}^{\infty}$. As before, (14) determines the two-period bond price, $\{Q_{2,t}\}_{t=0}^{\infty}$.[18] There is no role for either the maturity composition of the central bank's balance sheet ($b_{R,t}^{C}$) or of government debt ($b_{R,t}$). QE just redistributes government bonds in government and household portfolios.

***Discussion:*** QE is irrelevant in this standard model if conventional monetary policy follows either a credible commitment to a rule or a state-contingent policy, such that neither the government nor the central bank balance sheets affect current or future policy rates and (14) just determines the path of the two-period bond price, $\{Q_{2,t}\}_{t=0}^{\infty}$.

Chen, Cúrdia, and Ferrero (2012), Gertler and Karadi (2011, 2013), and Gertler and Kiyotaki (2010) introduce a role for QE with frictions by either having (14) apply only for a segment of the population (market participation constraints) or by breaking (14) with leverage constraints that limit arbitrage. Such frictions are necessary, but not sufficient for QE relevance. QE must be able to mitigate these frictions or affect the term premium. Subsection 2.2 details these issues.

We modeled conventional monetary policy as choosing the short-term policy rate, with (11) determining residually the demand for cash. Alternatively, one could ask if modeling QE as an expansion of the stock of money, funded by lump sum transfers, leads to a different conclusion. Such policy is referred to as "pure" QE in the literature. If short-term interest rates reach zero and real balances are at the satiation level, $m^*$, then interest rates cannot fall further, and any temporary expansion of real balances will have no effect (Krugman 1998). Permanent reserve expansion, which implies a higher money stock even when interest rates turn positive, however, would not be neutral (Auerbach and Obstfeld 2005). This is because a permanent and credible money stock expansion affects current macroeconomic variables by reducing the expected path

[17] We have modeled the Treasury policy in a simple but general way. The key is that the Treasury changes taxes to keep the government debt sustainable but does not necessarily fix the supply of Treasury bonds. This rules out the equilibrium emphasized in the fiscal theory of the price level because appropriate adjustments in taxes ensure that the intertemporal government budget constraints are satisfied for all possible paths of inflation and interest rates.

[18] Unlike before, the level of money balances $\{m_t\}_{t=0}^{\infty}$ is determined jointly with the rest of the model, because it enters the objective of the government.

of future interest rates, even if current rates are zero.[19]

We showed that changes in the composition of central bank or government balance sheets do not affect allocation in a model in which Ricardian equivalence holds. In other words, the evolution of neither (7) nor (10) matters for macroeconomic outcomes in such a model. The irrelevance of (7) and (10) means that *total* government debt, $b_t$, and *net position* of the central bank, $b_t^C$, are also irrelevant. In the next section we ask if the *composition* measures, $b_{R,t}$ and $b_{R.t}^C$, matter in a model without Ricardian equivalence where the *levels* of government debt and central bank net asset position, $b_t$ and $b_t^C$, are relevant.

***Extended model with fiscal policy:*** We now show that the maturity composition of government debt or central bank assets is irrelevant under optimal policy commitment, even without Ricardian equivalence. This discussion abstracts from cash and seigniorage for simplicity.

***Distortionary taxes and consolidated government:*** To be consistent with the literature inspired by Lucas and Stokey (1983), we first focus on the consolidated government that conducts monetary and fiscal policy jointly and uses distortionary labor taxes to finance its debt. We now describe how distortionary labor taxes change the baseline model.

The flow budget constraint of the household is now

$$\begin{aligned} Q_{1,t}b_{1,t}^H + Q_{2,t}b_{2,t}^H + Q_{1,t}l_{1,t}^H + c_t - (1-\tau_t^H)w_t h_t - \varphi_t \\ = \left[b_{1,t-1}^H + Q_{1,t}b_{2,t-1}^H + l_{1,t-1}^H\right]\Pi_t^{-1}, \end{aligned} \tag{18}$$

where $\tau_t^H$ is the labor tax rate and the rest of the notation is unchanged. The firms' environment and problem are unchanged. The consolidated government's flow budget constraint is

$$Q_{1,t}b_{1,t} + Q_{2,t}b_{2,t} + \tau_t^H w_t h_t = \left[b_{1,t-1} + b_{2,t-1}Q_{1,t}\right]\Pi_t^{-1}, \tag{19}$$

where tax revenues, $\Upsilon_t$, are now given by $\tau_t^H w_t h_t$ in (19). (12)-(14) and (16) still hold in this extended model, while the distorted labor supply condition is given by

$$\frac{U_c(c_t,h_t)}{U_h(c_t,h_t)} = -\frac{1}{(1-\tau_t^H)w_t}, \tag{20}$$

and where (15) is replaced by

$$\left[\left(\frac{\nu-1}{\nu}\right) + \frac{U_h(c_t,h_t)}{U_c(c_t,h_t)(1-\tau_t^H)}\frac{1}{A_t F_h(h_t)}\right]\nu y_t + \kappa(\Pi_t - 1)\Pi_t = \kappa\mathbb{E}_t\left[\Lambda_{t,t+1}(\Pi_{t+1}-1)\Pi_{t+1}\right]. \tag{21}$$

It is useful to consider a perfect foresight environment in which the asset pricing relationship (14) is given by $Q_{2,t} = Q_{1,t}Q_{1,t+1}$. Imposing this condition ex ante for all periods, the sequence of government flow budget constraints (19) can then be combined with a transversality condition

[19] Woodford (2012) discusses this in more detail. A permanent expansion of the monetary base shares elements with optimal commitment interest rate policy that we discuss under theories of FG.

to derive the present-value/intertemporal government constraint in period 0

$$\sum_{t=0}^{\infty} R_t^{-1}[\tau_t^H w_t h_t] = \frac{n_{-1}}{\Pi_0}, \tag{22}$$

where the interest rate factors are given by $R_0^{-1} \equiv 1$ and $R_t^{-1} \equiv \prod_{k=1}^{t} Q_{1,k-1}\Pi_k$ for $t \geq 1$, and where $n_{-1} \equiv \frac{N_{-1}}{P_{-1}}$. Equation (22) states that the present value of tax revenues in period 0 equals the real value of initial government liabilities.[20] Importantly, the maturity composition of government debt, i.e., $b_{R,t} \equiv \frac{Q_{2,t}b_{2,t}}{b_t}$, does not appear in it.

We can now show the irrelevance of QE, i.e., $b_{R,t}$, using arguments that echo those in Lucas and Stokey (1983) and Bhattarai, Eggertsson, and Gafarov (2019). Optimal policy under commitment (Ramsey policy) requires choosing a contingent path for the monetary and fiscal instruments $\{Q_{1,t}^{-1}, \tau_t^H\}_{t=0}^{\infty}$ in period 0 to maximize household welfare

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

subject to the constraints (12), (13), (16), (20), (21), and (22), taking as given initial government liabilities $n_{-1}$. The first-order conditions of this maximization problem, together with the constraints, pin down the path of $\{\Pi_t, Q_{1,t}, \tau_t^H, c_t, w_t, h_t\}_{t=0}^{\infty}$.

The *maturity composition* of government debt, $b_{R,t}$, has no role when monetary and tax policy is determined under commitment.[21] Total debt, $b_t \equiv Q_{1,t}(b_{1,t} + b_{2,t}Q_{1,t+1})$, is the only determined aspect of debt policy. It is implied by the sequential budget constraints (19),

$$Q_{1,t}[b_{1,t} + b_{2,t}Q_{1,t+1}] = [b_{1,t-1} + b_{2,t-1}Q_{1,t}]\Pi_t^{-1} - \tau_t^H w_t h_t, \tag{23}$$

as the government's optimal policy in period 0 pins down all right-hand-side variables.[22]

***Remittances to the Treasury and independent central bank:*** We now consider central bank balance sheet policy for an independent central bank with the flow budget constraint (7). As above, the sequential budget constraints can be combined to derive the period-0 constraint

$$\sum_{t=0}^{\infty} R_t^{-1} T_t = \frac{n_{-1}^C}{\Pi_0}, \tag{24}$$

where the interest rate factors are given by $R_0^{-1} \equiv 1$ and $R_t^{-1} \equiv \prod_{k=1}^{t} Q_{1,k-1}\Pi_k$ for $t \geq 1$, and

[20] We have abstracted from seigniorage; its inclusion would change (22) to $\sum_{t=0}^{\infty} R_t^{-1}[\tau_t^H w_t h_t + s_t] = \frac{n_{-1}}{\Pi_o}$.

[21] Perfect foresight simplification is not necessary to show the irrelevance of the maturity composition of government debt under commitment, if the government can issue state-contingent debt (Lucas and Stokey 1983).

[22] Thus, for period 0, we have $Q_{1,0}[b_{1,0} + b_{2,0}Q_{1,1}] = \frac{n-1}{\Pi_0} - \tau_0^H w_0 h_0$, which determines $Q_{1,0}[b_{1,0} + b_{2,0}Q_{1,1}]$. Since $Q_{1,0}$ is also determined, $b_{1,0} + b_{2,0}Q_{1,1}$ can then be used in period 1 to determine $Q_{1,1}[b_{1,1} + b_{2,1}Q_{1,2}]$, and so on.

where $n^C_{-1} \equiv \frac{N^C_{-1}}{P_{-1}}$. (24) simply states that the present value of transfers to the Treasury in period 0 equals the real value of initial central bank (net) assets.[23] The central bank's maturity mismatch in assets, i.e., $b^C_{R,t} \equiv \frac{Q_{2,t} b^C_{2,t}}{b^C_t}$, does not appear in it.

Now consider the case, as modeled in Bhattarai, Eggertsson, and Gafarov (2015), where the central bank cares about the dynamics of transfers to the Treasury, $T_t$. This concern may stem from worries about independence and will undermine Ricardian equivalence. The central bank maximizes the sum of household utility and its own utility from central bank transfers, $-Z(T_t)$, where $Z(T_t)$ is a convex function:

$$\sum_{t=0}^{\infty} \beta^t [U(c_t, h_t) - Z(T_t)]. \tag{25}$$

Under optimal conventional and UMP with commitment, the central bank chooses a contingent path for its instruments $\{Q^{-1}_{1,t}, T_t\}_{t=0}^{\infty}$ in period 0 to maximize (25), subject to the constraints (12), (13), (15), (16), and (24), taking as given the initial central bank asset position, $n^C_{-1}$. The first-order conditions of this maximization problem, together with the constraints, completely determine the path of $\{\Pi_t, Q_{1,t}, T_t, c_t, h_t\}_{t=0}^{\infty}$.

There is thus no role for $b^C_{R,t}$, the maturity composition of central bank's balance sheet. The only aspect of central bank balance sheet policy that is determined in equilibrium is the net asset position, $b^C_t \equiv Q_{1,t}[b^C_{1,t} + b^C_{2,t} Q_{1,t+1} - l^C_{1,t}]$, implied by the sequential budget constraints (7)

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

as the central bank's optimal policy in period 0 pins down all right-hand-side variables.

***Discussion:*** While we have shown that policy commitment renders the maturity composition of government debt, and thus QE, irrelevant, such a policy is *time inconsistent*. Forward-looking private-sector behavior gives the government an incentive to renege on past promises. If one focuses on a time-consistent equilibrium, where policy is conducted under discretion, then the maturity composition of government debt becomes relevant because the maturity composition of government debt *today* affects *conventional* monetary policy in the *future*. Similarly, for the central bank, the maturity structure of the central bank's assets *today* will affect the central bank's choice of *conventional* monetary policy in the *future*. Subsection 2.2 discusses this signaling channel of QE, modeled in Bhattarai, Eggertsson, and Gafarov (2015, 2019).

## 2.2 Models of effective quantitative easing

We now discuss general equilibrium macroeconomic models of QE from the literature.

[23] We have abstracted from seigniorage; its presence would change (24) to $\sum_{t=0}^{\infty} R_t^{-1}[T_t - s_t] = \frac{n^C_{-1}}{\Pi_0}$.

***Exogenous participation constraints in financial markets:*** Chen, Cúrdia, and Ferrero (2012) introduce exogenous participation constraints, building on the preferred habitat theory of the term structure (Vayanos and Vila 2009). In the model, 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. Without loss of generality, let's again suppose that the long-term bonds are two-period bonds. As the no-arbitrage asset pricing condition of the type (1) or (14) applies only to the unrestricted segment of the population, we have

$$\mathbb{E}_t\left[\Lambda_{t,t+1}^U\left(\frac{R_{2,t+1}}{\gamma_t} - R_{t+1}\right)\right] = 0, \tag{26}$$

where $\Lambda_{t,t+1}^U$ is the SDF of the unrestricted agent and $\gamma_t$ is the transaction cost of participating in both markets. The Euler equation of the restricted agents is defined only for long-term bonds,

$$\mathbb{E}_t\left[\Lambda_{t,t+1}^R R_{2,t+1}\right] = 1, \tag{27}$$

where $\Lambda_{t,t+1}^R$ is the SDF of the restricted agent.[24]

The transaction cost plays an important role; market segmentation alone would not produce the results of Chen, Cúrdia, and Ferrero (2012). A linear approximation illustrates this point. Without the transaction cost, a linearized (26) would have no term premium,

$$\mathbb{E}_t\left[R_{2,t+1} - R_{t+1}\right] = 0 \text{ or } Q_{2,t} = Q_{1,t} + \mathbb{E}_t Q_{1,t+1},$$

which simply reflects the expectations hypothesis. With the transaction cost, the term premium exists and linearization of (26) gives

$$\mathbb{E}_t\left[R_{2,t+1} - R_{t+1}\right] = \gamma_t \text{ or } Q_{2,t} = Q_{1,t} + \mathbb{E}_t Q_{1,t+1} - \gamma_t. \tag{28}$$

Chen, Cúrdia, and Ferrero (2012) assume that the transaction cost is a decreasing function of the ratio of central bank holdings of two-period bonds to one-period bonds: $\gamma_t \equiv \gamma\left(B_{R,t}^C\right)$.

Central bank purchases of long-term bonds reduce the term premium but this does not suffice to produce macroeconomic effects.[25] Without exogenous participation constraints, only (28) would hold (there would be no separate Euler equation (27)), which would then imply that long-term bond prices would adjust to equalize expected returns across the two assets and the SDF would not change. Thus, as in the simple model above, the condition that determines the long-

[24] Vayanos and Vila (2009) model two types of agents: "Preferred habitat investors," agents who have a (price-elastic) demand for bonds of specific maturities only and do not substitute across maturities; and "Arbitrageurs," investors with mean-variance preferences who operate across all bond markets and ensure that the term structure is arbitrage free. Hamilton and Wu (2012) show that such a set-up can rationalize the no-arbitrage conditions for a standard affine term structure model.

[25] Some papers create a similar channel for QE by directly introducing long-term bonds in a utility function or assuming imperfect substitution between long- and short-term bonds in preferences (Harrison 2012; Alpanda and Kabaca 2020). Tobin (1958, 1969), Brunner and Meltzer (1973), and Andrés, López-Salido, and Nelson (2004) provided earlier, pre-ZLB work on portfolio balance effects due to imperfect asset substitutability.

term bond return would still determine long-term bond prices residually.

The combination of market segmentation and a transaction cost means that QE changes long-term yields and produces macroeconomic effects because (27) becomes part of the model equilibrium. For (27) to hold, the SDF of the restricted household must change. In particular, after linearization, (27) is given by

$$\mathbb{E}_t\left[\Lambda^R_{t,t+1}\right] = \mathbb{E}_t\left[R_{2,t+1}\right].$$

Then it is clear that if $R_{2,t+1}$ changes, $\Lambda^R_{t,t+1}$ (and thus restricted household consumption) will change. Central bank purchases of long-term bonds will change $B^C_{R,t}$ and thus $R_{2,t+1}$, which will in turn change macroeconomic quantities and prices.[26]

***Limits to arbitrage due to leverage constraints:*** Gertler and Karadi (2011, 2013) and Gertler and Kiyotaki (2010) introduce binding leverage constraints on intermediaries. Their model features a general version of the no-arbitrage relation (1), where the rate of return, $R_{L,t+1}$, is on capital,

$$\mathbb{E}_t\left[\Lambda_{t,t+1}(R_{L,t+1} - R_{t+1})\right] \geq 0. \tag{29}$$

When leverage constraints bind for financial intermediaries, their inability to increase borrowing/leverage means that (29) holds with a strict inequality

$$\mathbb{E}_t\left[\Lambda_{t,t+1}(R_{L,t+1} - R_{t+1})\right] > 0. \tag{30}$$

The difference between the (risk-adjusted) returns on long-term assets (capital) and the risk-free asset (short-term government bond) in (30) is called the external finance premium. Even with a linear approximation, excess returns on capital arise in equilibrium.

The key friction that produces the leverage constraints is that banks, which intermediate between households and non-financial firms, can abscond with funds. Banks own claims on capital, $K_t$, of non-financial firms, where the price of capital is $S_t$, while banks borrow $B_{1,t}$ from households, at the one-period risk-free rate, leaving banks with net worth $NW_t$. Thus, we have

$$NW_t = S_t K_t - Q_{1,t} B_{1,t}, \tag{31}$$

with the flow constraint of financial intermediaries given by

[26] Wu and Zhang (2019a) develop a related model where the Euler equation of the type (27) that is defined only for long-term bonds applies for the representative household. There is no Euler equation for short-term bonds. This set-up thus incorporates a version of market segmentation as presented above. Wu and Zhang (2019a) assume that the central bank can directly affect the long-term rate through unmodeled QE and FG. Wu and Zhang (2019b) embed the Wu and Zhang (2019a) set-up in a two-country model, while Mouabbi and Sahuc (2019) do so in a quantitative macro model. Carlstrom, Fuerst, and Paustian (2017) develop an alternative model of market segmentation in which only financial intermediaries, and not households, may buy long-term debt. Financial intermediaries cannot perfectly arbitrage interest rate differentials, and central bank purchases of long-term bonds decrease long-term yields and raise real activity because firms must finance investment with long-term debt.

$$NW_{t+1} = R_{L,t+1}S_tK_t - B_{1,t} = R_{t+1}NW_t + (R_{L,t+1} - R_{t+1})S_tK_t, \tag{32}$$

which shows that net worth evolves over time via retained earnings.

Let $V_t$ be the value of a bank, its expected terminal net worth given the random bank exit rate, $\theta$. As a bank can abscond with a fraction, $\lambda$, of its assets, the incentive constraint is

$$V_t \geq \lambda S_t K_t. \tag{33}$$

Banks maximize $V_t$ subject to the flow constraint (32) and the incentive constraint (33).[27] If the incentive constraint (33) binds, the following leverage constraint holds with equality

$$S_t K_t = \phi_t NW_t, \tag{34}$$

where the leverage ratio $\phi_t$ is endogenously and optimally determined.

How is $\phi_t$ determined? In equilibrium, $V_t$ is a linear function of $S_tK_t$ and $NW_t$: $V_t = v_t S_t K_t + \eta_t NW_t$. Here, $v_t$ is the discounted gain of one more unit of capital, holding net worth constant, while $\eta_t$ is the discounted gain of one more unit of net worth, holding capital constant. When (33) holds with equality, then it together with (34) and the linear solution for $V_t$ implies $\phi_t \equiv \frac{\eta_t}{\lambda - v_t}$. Moreover, $v_t = \lambda \frac{\Xi_t}{1+\Xi_t}$, where $\Xi_t$ is the Lagrange multiplier on the constraint (33).[28]

When the incentive constraint, (33), and thereby the leverage constraint, (34), bind, limits to arbitrage create a wedge between the expected return on capital and risk free debt. That is,

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\Theta_{t+1}(R_{L,t+1} - R_{t+1})\right] = v_t = \lambda \frac{\Xi_t}{1+\Xi_t}, \tag{35}$$

where $\Theta_t = (1-\theta) + \theta(\eta_t + v_t\phi_t)$. (35) makes clear that the external finance premium exists when $\Xi_t > 0$. In the models of Gertler and Karadi (2011, 2013) and Gertler and Kiyotaki (2010), this premium depends inversely on the financial intermediaries' net worth $NW_t$, which then becomes a key state variable (that evolves as in (32)) and leads to amplification of shocks.[29]

When leverage constraints on financial intermediaries bind and financial shocks raise the external finance premium, government credit policy can be used countercyclically. Gertler and Karadi (2011) model QE as direct financial intermediation by the central bank. The central bank lends less efficiently than the private sector but is not subject to the leverage constraint (34), the key friction that leads to limits to arbitrage and the external finance premium. It can issue risk-

[27] Formally, $V_t = \max\,(1-\theta)\mathbb{E}_t \sum_{i=0}^{\infty} \theta^i \Lambda_{t,t+1+i} NW_{t+1+i}$. The financial friction and the random exit rate means that it is optimal for banks to accumulate net worth until exit. We drop bank-specific notation for clarity. The aggregate evolution of bank net worth will differ slightly due to entry and exit of banks.

[28] Thus, in models without the incentive constraint/financial friction, $v_t = 0$ as $\Xi_t = 0$.

[29] Brunnermeier and Sannikov (2016) also develop a model of financial frictions where the net worth of financial intermediaries plays a role in amplifying shocks. They consider a central bank that conducts short-term interest rate policy and open market operations to keep a constant ratio of fiat money to long-term government bonds. Such a policy mitigates adverse shocks by recapitalizing financial intermediaries through long-term bond price changes.

free debt to raise funds elastically from households and use such funds to finance non-financial firms. Intermediation is the sum of the private and government components,

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

where $K_{t,p}$ and $K_{t,g}$ are private and government claims on non-financial firms, respectively.

Suppose that the government does $\psi_t$ percent of total financing, with $K_{t,g} = \psi_t K_t$. $\psi_t$ is a measure of credit policy, and Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) consider feedback rules of the type

$$\psi_t = \Upsilon \mathbb{E}_t\left[R_{L,t+1} - R_{t+1}\right],$$

where $\Upsilon > 0$. Government intermediation is not subject to the credit constraint, and it reduces the cost of funding and boosts consumption/output in the face of negative financial shocks.[30]

Gertler and Karadi (2013) extend the setup in Gertler and Karadi (2011) to analyze the central bank purchases of long-term (2-period here) government bonds from financial intermediaries. Therefore, the balance sheet (31) and flow constraint (32) now become

$$NW_t = S_t K_t + Q_{2,t} B_{2,t} - Q_{1,t} B_{1,t},$$

$$NW_{t+1} = R_{L,t+1} S_t K_t + Q_{1,t+1} B_{2,t} - B_{1,t}$$

$$= R_{t+1} NW_t + \left(R_{L,t+1} - R_{t+1}\right) S_t K_t + \left(R_{2,t+1} - R_{t+1}\right) Q_{2,t} B_{2,t}.$$

The incentive constraint (33) becomes

$$V_t \geq \lambda S_t K_t + \kappa Q_{2,t} B_{2,t},$$

because 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 ($\kappa$ vs. $\lambda$). A condition, analogous to (35), then also holds for long-term government bonds:

$$\mathbb{E}_t\left[\Lambda_{t,t+1} \Theta_{t+1} (R_{2,t+1} - R_{t+1})\right] = \kappa \frac{\Xi_t}{1+\Xi_t}. \quad (36)$$

In this extended set-up then, the government can issue short-term bonds to fund long-term bond purchases, which reduces the interest rate spread. The reasoning is identical to that described above for the simple set-up with government credit provision. By comparing (35) with

[30] Gertler and Kiyotaki's (2010) model features the financial friction in intermediation described above, as well as idiosyncratic liquidity/investment shocks across firms/banks. Firms reside on islands and banks can only lend to firms on their island, providing a rationale for interbank lending. Gertler and Kiyotaki (2010) use the model to analyze discount window lending and direct equity injections. Discount window lending and credit provision have macroeconomic effects because the central bank can enforce repayment. The central bank can also inject equity into financial intermediaries, paying above-market prices for the claims, and banks cannot divert assets financed by such injections. This policy increases banks' net worth, which mitigates the rise of the external finance premium.

(36), we see that the following no-arbitrage condition holds

$$\lambda \mathbb{E}_t\left[\Lambda_{t,t+1}\Theta_{t+1}(R_{2,t+1} - R_{t+1})\right] = \kappa \mathbb{E}_t\left[\Lambda_{t,t+1}\Theta_{t+1}(R_{L,t+1} - R_{t+1})\right],$$

which means that government purchases of long-term bonds reduce both excess returns.

Sims and Wu (2019a) further extend Gertler and Karadi's (2013) setup by modeling interest-bearing reserves issued by the central bank. Financial intermediaries hold these reserves, subject to a reserve requirement that is proportional to deposits. Banks have no incentive problem in holding reserves, however, as they can't be stolen. Firms can finance investment only by issuing long-term bonds; QE is central bank purchases of private or government long-term bonds in exchange for central bank reserves. Such a policy reduces interest rate spreads for the same reasons as in the Gertler and Karadi (2013) model described above.[31]

***Signaling channel under time-consistent policy:*** Bhattarai, Eggertsson, and Gafarov (2015, 2019) provide a theory for the signaling channel of QE in a model with perfect foresight and thus no term-premia, but without financial frictions/participation constraints. The key difference from Subsection 2.1 is that Bhattarai, Eggertsson, and Gafarov (2015, 2019) study time-consistent discretionary policy—not assuming commitment—and show that the maturity composition of government debt affects optimal future interest rates. In particular, QE signals lower future short-term interest rates and thereby reduces current long rates.

To understand why the maturity composition of government debt matters under time-consistent policy, impose $Q_{2,t} = Q_{1,t}Q_{1,t+1}$ on the government's budget constraint (19)

$$Q_{1,t}\left[b_{1,t} + b_{2,t}Q_{1,t+1}\right] + \tau_t^H w_t h_t = \left[b_{1,t-1} + b_{2,t-1}Q_{1,t}\right]\Pi_t^{-1}. \tag{37}$$

The *maturity* value of short- and long-term debt, $b_{1,t-1}$ and $b_{2,t-1}$, are the relevant state variables for the government's optimization problem in period $t$.[32] The right-hand side of (37) shows *two distinct* sources of time inconsistency in the model. The first is associated with period-t inflation ($\Pi_t$), which is due to nominal debt inherited from last period and is independent of the maturity composition. The second is associated with the period-t bond price/interest rate ($Q_{1,t}$), which exists only if there is long-term debt inherited from last period that can be re-priced today.

Under discretion, the government recognizes that current expectations are functions of today's choice variables, which are state variables for tomorrow's government. To show the role for the maturity composition of debt under discretion, we define the maturity value of debt ($b_t$) and the share of long-term debt ($\rho_t$) as $b_t = b_{1,t} + b_{2,t}$ and $\rho_t = \frac{b_{2,t}}{b_t}$. We can then write (37) as

[31] Sims and Wu (2019b) develop a simpler version of the Sims and Wu (2019a) model that only deviates minimally from the textbook sticky price model but can still be used to analyze QE.

[32] Formally, the solution concept is Markov perfect equilibrium. The maturity value of the two types of debt, which are inclusive of interest payments, are sufficient minimum state variables for the government's problem.

$$(1-\rho_t)b_t + Q_{1,t+1}\rho_t b_t + Q_{1,t}^{-1}\tau_t^H w_t h_t = \left[Q_{1,t}^{-1}(1-\rho_{t-1})b_{t-1} + \rho_{t-1}b_{t-1}\right]\Pi_t^{-1}. \quad (38)$$

Under time-consistent policy, the government chooses its current instruments, $Q_{1,t}^{-1}$, $\rho_t$, and $b_t$, to maximize household welfare. This problem is written recursively as

$$V(\rho_{t-1}, b_{t-1}, A_t) = \max_{\{Q_{1,t}^{-1}, \rho_t, b_t\}} \left[U(c_t, h_t) + \beta V(\rho_t, b_t, A_{t+1})\right],$$

subject to

$$Q_{1,t}^{-1} \geq 1, \beta\overline{\Lambda_{t,t+1}\Pi_{t+1}^{-1}}Q_{1,t} = 1,$$

$$\left[\left(\frac{\nu-1}{\nu}\right) + \frac{U_h(c_t,h_t)}{U_c(c_t,h_t)(1-\tau_t^H)}\frac{1}{A_t F_h(h_t)}\right]\nu y_t + \kappa(\Pi_t - 1)\Pi_t = \kappa\overline{\Lambda_{t,t+1}(\Pi_{t+1}-1)\Pi_{t+1}},$$

$$y_t = A_t F(h_t) = c_t + \frac{\kappa}{2}(\Pi_t - 1)^2,$$

$$(1-\rho_t)b_t + \overline{Q_{1,t+1}}\rho_t b_t + Q_{1,t}^{-1}\tau_t^H w_t h_t = \left[Q_{1,t}^{-1}(1-\rho_{t-1})b_{t-1} + \rho_{t-1}b_{t-1}\right]\Pi_t^{-1},$$

$$\frac{U_c(c_t,h_t)}{U_h(c_t,h_t)} = -\frac{1}{(1-\tau_t^H)w_t},$$

where $V(\rho_{t-1}, b_{t-1}, A_t)$ is the government's value function. Crucially, for all future variables, $x_{t+1}$, that appear in the private sector equilibrium conditions above in period $t$, we have used the notation $\overline{x_{t+1}}$ to denote that the government in period $t$ recognizes that the expectations will all be *functions* of the state variables, $\rho_t$, $b_t$, and $A_{t+1}$, in period $t+1$.[33] Thus, this presentation of the government's problem makes it clear that the *maturity composition of government debt* is an independent state variable, holding *total level of debt constant*.

How does the maturity composition of government debt in period $t-1$ affect the government's choice of the policy rate in period $t$? And how does reducing $\rho_{t-1}$ help when a zero lower bound is binding? Bhattarai, Eggertsson, and Gafarov (2019) label the term $\frac{1}{Q_{1,t}}(1-\rho_{t-1})$ in (38) as the "roll-over incentive" of the government because with less long-term debt from period $t-1$, the government in period $t$ must roll over more short-term debt. The interest rate $Q_{1,t}^{-1}$ applies to this stock of debt to be rolled over. When the government inherits less long-term debt, such that $(1-\rho_{t-1})$ is high, it will have an incentive to keep the policy rate, $Q_{1,t}^{-1}$, low because then it will have to rely less on inflation and/or distortionary taxes.[34]

Thus, the optimal time-consistent policy in the model of Bhattarai, Eggertsson, and Gafarov

[33] Note that we have imposed perfect foresight. In any period $t$, we only impose those asset pricing conditions determined in period $t$ and not those from period $t-1$. This is a crucial difference from the commitment case, where we imposed ex ante asset pricing conditions on all future periods that enabled us to derive a present value budget constraint in period 0 that has no role for maturity composition and was the government's only constraint.

[34] The period-1 government, for instance, understands that the intertemporal budget constraint $\sum_{t=1}^{\infty} R_t^{-1}[\tau_t^H w_t h_t] = \left[Q_{1,1}^{-1}(1-\rho_0)b_0 + \rho_0 b_0\right]\Pi_1^{-1}$ applies in equilibrium.

(2019) is to lower $\rho_{t-1}$ when the ZLB binds, because that provides incentives for the government in period $t$ to lower interest rates, which improves outcomes today. That is, the central bank will raise the short-term policy rate more slowly, which then affects today's expectations about the economy and lessens the recessionary effects of the ZLB.[35]

While the above has described the unified government's problem, Bhattarai, Eggertsson, and Gafarov (2015) also consider the case of an independent central bank, such as the one discussed in Subsection 2.1. Consider again the flow budget constraint of the central bank (7):

$$Q_{1,t}\left[b_{1,t}^{C} + b_{2,t}^{C}Q_{1,t+1} - l_{1,t}^{C}\right] = \left[b_{1,t-1}^{C} + b_{2,t-1}^{C}Q_{1,t} - l_{1,t-1}^{C}\right]\Pi_t^{-1} - T_t, \tag{39}$$

which shows that the *maturity* value of the central bank's two-period asset and net debt, $b_{2,t-1}^{C}$ and $b_{1,t-1}^{C} - l_{1,t-1}^{C}$, are the relevant state variables for the discretionary problem.

As before, we can define the total maturity value of net assets ($b_t^c$) and the share of long-term assets ($\rho_t^c$) as $b_t^c = b_{1,t}^c - l_{1,t}^C + b_{2,t}^C, \rho_t^c = \frac{b_{2,t}^C}{b_t^C}$. Then, we rewrite (39) as

$$\left[(1-\rho_t^c)b_t^C + Q_{1,t+1}\rho_t^c b_t^C\right] + Q_{1,t}^{-1}T_t = \left[Q_{1,t}^{-1}(1-\rho_{t-1}^c)b_{t-1}^C + \rho_{t-1}^c b_{t-1}^C\right]\Pi_t^{-1},$$

which makes clear that the two state variables for the central bank's problem are $\rho_{t-1}^C$ and $b_{t-1}^C$. Thus, the maturity *composition of the central bank's assets* is an independent state variable, even holding *constant the central bank's net asset position*. A larger maturity mismatch in the central bank balance sheet gives an incentive to keep the policy rate low, for the same reasons as in the consolidated government case (Bhattarai, Eggertsson, and Gafarov 2015).[36]

We now briefly discuss some other important models of QE.

***Credit spreads and heterogeneity:*** Cúrdia and Woodford (2011) use a borrower-saver model with credit frictions to analyze "pure" QE and credit easing policies. Households switch between being borrowers and savers, and competitive banks channel funds from savers to borrowers. As this intermediation uses real resources, a (credit) spread between borrowing and saving rates arises endogenously, which increases in the supply of credit. The central bank's liabilities are interest-bearing reserves, while its assets are loans to households and government bonds.

Pure QE expands central bank reserves and is irrelevant in the Cúrdia and Woodford (2011) model. That is, beyond a satiation level, expansion of central bank reserves has no effect on macroeconomic prices and quantities, for the reasons we emphasized in Subsection 2.1. Cúrdia and Woodford (2011) therefore generalize the irrelevance of pure QE shown in Eggertsson and Woodford (2003) to a model with two types of households and financial frictions.

Credit policy is direct lending by the central bank, and it is not neutral in the Cúrdia and

[35] Bhattarai, Eggertsson, and Gafarov (2019) solve a simpler finite-horizon model nonlinearly.

[36] Bhattarai, Eggertsson, and Gafarov (2015) solve their model with a linear approximation for the case in which the central bank net asset position is below its steady-state at the ZLB.

Woodford (2011) model, unlike Eggertsson and Woodford (2003). The composition of central bank assets matters because the former model features intermediation frictions, but the latter model does not. When financial shocks raise the credit spread, the central bank supplies credit to the private sector to mitigate the consequences. It decreases credit supplied by private intermediaries and thus also the spread. The effects are the same whether the government/central bank finances increased lending by expanding reserves or by reducing government debt.

***Incomplete asset market participation:*** Farmer and Zabczyk (2016) construct a two-period model with incomplete asset market participation that delivers a Pareto inefficient competitive equilibrium. The central bank can achieve the efficient allocation through UMP in which it issues indexed bonds and buys stocks with the proceeds.

### 2.3 Other unconventional monetary policy

We now discuss FG and negative interest rates, two UMP tools with which central banks have supplemented QE.

***Forward Guidance:*** Major central banks have augmented asset purchases with FG at the ZLB to shape market expectations of expansionary conventional monetary policy—i.e., of keeping policy rates lower for longer than the usual reaction function would indicate. FG may be Delphic or Odyssean. That is, it may predict future economic conditions or it may commit the central bank to a future course of action (Campbell et al. 2012).[37] The FOMC's famous "dot plot" is an example of (mostly) Delphic guidance as it tries to communicate the committee's view of economic conditions and its own reaction function. Both sorts of guidance are subject to inconsistency. Central banks probably don't have systematically superior information about the economy to consistently provide Delphic guidance, although they might in some circumstances. Neither is it clear that central banks can commit themselves to future actions that are time-inconsistent (Krugman 1998).

We now illustrate how the theory of Odyssean FG depends on the formulation of monetary policy. First, consider monetary policy as being determined optimally under commitment, as in Subsection 2.1. In period 0 the central bank chooses a contingent path for its instrument $\{Q_{1,t}^{-1}\}_{t=0}^{\infty}$ to maximize household welfare, subject to the private sector equilibrium conditions. Under commitment, optimal monetary policy at the ZLB entails a promise to keep the short rate at zero in the future, even when it is feasible to raise it (Eggertsson and Woodford 2003; Jung, Teranishi, and Watanabe 2005; Werning 2012). If such policy is credible to the private sector,

[37] The term "Delphic" comes from the ancient Greek Oracle of Delphi, 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.

anticipation of lower future short rates boosts current inflation and output.[38]

Importantly, the *endogenous* duration for which interest rates stay at zero under commitment policy is longer than under purely forward-looking policy, such as under no-commitment. Commitment policy features *history dependence*, unlike purely forward-looking policy, and it can be implemented using a time-varying price *level* target (Eggertsson and Woodford 2003).

A second way to rationalize FG is through feedback policy rules. That is, suppose that policy is conducted using (17) as in Subsection 2.1, but with a "news" shock $\varepsilon_{t-k}$ that represents FG:

$$\beta Q_{1,t}^{-1} = \left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \exp\left(\varepsilon_{t-k}\right), \tag{40}$$

where $k$ is the horizon of FG. Here, expansionary FG produces expectations of a negative $\varepsilon_t$, $k$ quarters ahead, that affects macroeconomic outcomes today. The equilibrium is determined by (13), (15), (16), and (40), subject to (12). At positive rates, a FG shock raises inflation and also real output today under many parameterizations. At the ZLB, FG of lower future rates then raises output and inflation today through the expected future effects of short real rates.[39]

***Negative interest rates:*** Some central banks (e.g., the ECB and BOJ) have implemented NIRP on central bank reserve balances. Traditionally, it has been thought that interest rates cannot fall (much) below zero because lenders would hold cash rather than accept negative nominal returns.[40] Subsection 2.1 shows such a result in macroeconomic models with fiat money.

How can the standard model of household money demand described in Subsection 2.1 be altered to account for NIRP? Rognlie (2016) extends the baseline model to keep money demand finite at negative rates. The key idea is that $W_m$ is positive up to $m^*$, as in Subsection 2.1, but beyond $m^*$, the marginal utility from holding real balances is not zero but is instead negative. That is, $W_m > 0$ when $m_t < m^*$ while $W_m < 0$ when $m_t > m^*$. $W(m^*)$ thus represents the global maximum of $W(.)$, reached at zero interest rates. Then, positive interest rates correspond to $W_m > 0$ , while negative interest rates correspond to $W_m < 0$.

Some models rationalize an equilibrium with NIRP on central bank reserves by modeling negative rates as a tax on financial intermediaries. For instance, Sims and Wu (2019a) assume that intermediaries must hold a minimum level of reserves. When such a reserve requirement binds, interest rates on reserves are below the rate on household deposits, but the ZLB applies only to the household deposit rate. In Eggertsson et al. (2019), central bank reserves provide "transaction services" for banks and thus banks are willing to hold them even at negative rates.

The policy rationale for negative rates is that they stimulate the economy much like a policy

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[38] Thus, FG and the signaling channel of QE discussed earlier are substitutes as the signaling channel is in operation only while focusing on a time-consistent equilibrium (under no-commitment).

[39] In fact, in standard models, such a news shock has implausibly large effects, with these effects increasing in the horizon of FG. Del Negro, Giannoni, and Patterson (2015) have labelled this the *forward guidance puzzle*.

[40] Some central banks have been able to set their policy rates more than 50 to 75 b.p. below zero.

cut in positive territory. Some papers, however, argue that negative rates below a certain level are contractionary because they reduce net interest margins and bank profits, lowering banks' net worth and tightening their capital constraint, which decreases lending. Brunnermeier and Koby (2018) refer to the rate below which cuts are contractionary as the "reversal interest rate." Below this rate, the adverse effect on the financial system of cuts outweighs any expansionary influence. Eggertsson et al. (2019) also point out that negative interest rates might be contractionary if the household deposit rate is downwardly rigid and limits the pass-through of NIRP to lending rates, a feature not required for the Brunnermeier and Koby (2018) result. Ulate (2019) shows that if the banking sector is monopolistically competitive, then NIRP need not always be contractionary, unlike in Eggertsson et al (2019), as the lending rate can then decline.

# 3 The modern practice of unconventional monetary policy

This section describes UMP by the four major central banks from 1999 through 2019. Neely and Karson (forthcoming) provide more detail.[41]

***Bank of Japan reserve targeting in 1999-2006:*** After lowering its policy rate to zero in 1999, the BOJ pioneered the modern use of UMP with FG and the targeting of the quantity of bank reserves. That is, it tried to shape expectations of zero interest rates until "deflationary concerns are dispelled" and purchased Japanese government bonds (JGBs) and asset-backed securities (ABS) to boost reserves (Okina and Shiratsuka 2004; Bank of Japan 2001).[42] After five years of QE, on March 9, 2006, the BOJ cited a transient CPI uptick in reverting to the overnight interest rate as its main policy tool. The BOJ expressed a lack of confidence in UMP, stating that effects on economic activity and prices "mainly result from" short-term interest rates (Bank of Japan 2006).

***Federal Reserve and Bank of England broad-based asset purchases:*** The Fed and BOE faced similar economic problems after the 2007-2009 financial crisis. Having lowered their policy rates near zero (upper panel of Figure 1), the Fed and BOE then launched broad bond purchase programs to reduce long yields, ensure market functioning, provide stimulus, and hit their inflation targets.

[Figure 1 here]

From 2008-2014 the Fed conducted four QE programs to ease financial conditions and reduce long-term yields to achieve its mandated price stability and employment objectives. The programs differed in quantity and type of bond purchased, funding method, and whether purchases were pre-announced or open-ended. QE1 purchased $1.725 trillion of mortgage-backed securities (MBS), housing government-sponsored enterprise (GSE) debt, and Treasuries to boost the housing market. These purchases more than doubled the U.S. monetary base. QE2 purchased $600 billion in long-term Treasuries. Sales of short-term Treasury bills, rather than

[41] Haas, Neely, and Emmons (forthcoming) describe central bank policy responses to the COVID-19 crisis in 2020.
[42] The BOJ terms bank reserves as "current accounts."

monetary expansion, funded the Maturity Extension Program's (MEP) purchases of $667 billion in long-term Treasuries.[43] QE3 was an open-ended and contingent program, eventually purchasing $85 billion in Treasury and MBS bonds each month, rather than a specified lump sum (see Bullard 2010). The practice of open-ended and contingent programs became the norm for central bank asset purchase programs. Together, these asset purchases more than quintupled the Fed's asset holdings by 2015 (Figure 2).

[Figure 2 here]

In January 2009, the BOE announced an asset purchase facility (APF) that would initially buy £50 billion in commercial paper and corporate bonds. It repeatedly increased these purchases of medium- and long-term gilts over 2009-2016 (Figure 2). Although the APF initially sterilized its long-bond purchases by selling short-term gilts, it soon switched to funding with reserve creation, which greatly increased the U.K. monetary base by the end of 2009 (Figure 2).

***Federal Reserve and Bank of England forward guidance:*** The Fed and BOE used FG to shape policy expectations in very different ways. The BOE only used FG for a short time in 2013-2014, but the Fed used it extensively, in three phases: ambiguous time-based guidance, date-based guidance, and state-contingent guidance (Williams 2016). For example, the March 18, 2009, Federal Open Market Committee (FOMC) statement read that "economic conditions are likely to warrant exceptionally low levels of the federal funds rate for an extended period." The date-based August 9, 2011, statement amended that to exceptionally low levels for the federal funds rate "at least through mid-2013." Finally, on December 12, 2012, the FOMC began conditioning guidance on unemployment and inflation, which appeared to flatten the implied path from futures prices (see Figure 3).[44] A consensus emerged that both QE and FG should be linked to the state of the economy rather than the calendar (Bullard 2010; Feroli et al. 2017).

[Figure 3 here]

***The ECB responds to the debt crisis with the SMP/OMT:*** The Fed and BOE bond purchase programs broadly depressed yields to provide general stimulus. But the ECB initially responded to the financial crisis in a more limited way, with only expanded liquidity provision, because it perceived less impact of the crisis on the euro area. In addition, the ECB faced legal and practical hurdles to a broad bond buying program, including how to apportion bond purchases.

Instead, the first major ECB asset purchase program had narrower purposes: to support sovereign debt markets beleaguered by crisis-related deficits.[45] In May 2010, the ECB introduced the Securities Markets Programme (SMP) to purchase government debt on an as-needed basis to promote depth and liquidity and reduce yields in troubled euro-area, sovereign-

[43] Operation Twist in the early 1960s was an antecedent to the modern Maturity Extension Program in which the Fed attempted to lower the long end of the yield curve while keeping short rates up.
[44] https://www.federalreserve.gov/monetarypolicy/timeline-forward-guidance-about-the-federal-funds-rate.htm
[45] Smaller ECB-covered bond purchase programs (CBPP and CBPP2) funded banks and maintained credit for households and firms (Trichet 2009; European Central Bank 2012).

debt markets (European Central Bank 2010). In September 2012, the ECB replaced the SMP with the Outright Monetary Transactions (OMT) program, which included an enforcement mechanism to ensure that countries whose debt was purchased took steps to regain fiscal solvency. Although the ECB has not purchased bonds through the OMT, policymakers credit its announcement with quelling fears of default and the dissolution of the euro area (Cœuré 2013).

***Banking support programs:*** The BOE and BOJ created conditional credit programs to support and incentivize bank lending in 2012. The BOE's Funding for Lending Scheme (FLS) lent U.K. Treasury bills to banks to use as collateral, to boost domestic lending (Bank of England 2012; Churm et al. 2012). The FLS eventually grew to a peak of 3.6 percent of U.K. GDP before the BOE officially ended new drawdowns on January 31, 2018. The BOE would later establish the Term Funding Scheme (TFS) in 2016, which lent money, not U.K. Treasury bills to use as collateral (see Bank of England 2016).

The BOJ soon followed with the Stimulating Bank Lending Facility (SBLF), which would grow to 7.4 percent of GDP in Q4 2017, becoming the largest conditional lending program relative to nominal GDP among those administered by the four major central banks. The BOJ intends to end SBLF loan disbursements in 2021 (Bank of Japan 2019).

The ECB would later establish similar programs, known as Targeted Longer-Term Refinancing Operations—i.e., TLTRO in 2014, TLTRO II in 2016, and TLTRO III in 2019—to provide longer-term funding and incentives for lending (Draghi 2014a).

The SBLF, FLS, TLTRO, TLTRO II, TLTRO III and TFS employed quantity or price incentives for bank lending to households and businesses and often offered unusually long borrowing horizons of 3 to 4 years, which reduced rollover and transformation risk.[46]

***The BOJ enacts "Abenomics" in 2013-2019:*** After Prime Minister Shinzo Abe's landslide victory in late 2012, the BOJ moved strongly to counter persistently sluggish economic activity with a series of policies including a doubling of the inflation target from 1 to 2 percent and "Quantitative and Qualitative Easing" (QQE) that used open-ended, contingent asset purchases to increase the size and maturity of the BOJ's assets. Japanese authorities sought to drastically change expectations to achieve 2 percent inflation within two years (Bank of Japan 2013). The BOJ would repeatedly extend and expand its UMP to counter renewed deflationary pressures (Figure 2) and would introduce negative deposit rates in January 2016 (lower panel of Figure 1).

Despite these measures, Japanese inflation continued to be undesirably low and yield curve inversion threatened the profitability of Japanese financial firms. In September 2016, the BOJ responded with "QQE with Yield Curve Control" that targeted both the overnight deposit rate and the 10-year JGB yield at -0.1 percent and 0.0 percent, respectively, to achieve the 2 percent inflation target. The BOJ thus became the only central bank to explicitly target long-dated yields.

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[46] The SBLF complemented an earlier, smaller, lending facility called the Growth-Supporting Funding Facility (GSFF), announced on May 21, 2010 (Bank of Japan Monetary Affairs Department 2010).

Governor Kuroda also committed to maintain asset purchases until inflation "exceeds the price stability target of 2 percent and stays above the target in a stable manner" (Bank of Japan 2016).

***The ECB responds to deflation fears:*** From late 2013 to 2017, the ECB Governing Council fought undesirably low inflation with lower policy rates, conditional bank lending programs, further asset purchases, and negative deposit rates. In 2014, the ECB became the first major central bank to set a negative deposit rate (-0.1 percent) on excess reserves (lower panel of Figure 1), which Governing Council couched in terms of ensuring price stability (European Central Bank 2014).

The ECB's varied asset purchase programs included an Asset-Backed Securities Purchase Programme (ABSPP), a new Covered Bond Purchase Programme (CBPP3), a Public Sector Purchase Programme (PSPP), and a Corporate Sector Purchase Programme (CSPP). ECB President Draghi described CBPP3 and ABSPP as *credit easing*, not QE, because they supported covered bond and ABS markets, although they also expanded the ECB's asset holdings (Draghi 2014b; Figure 2). The Public Sector Purchase Programme (PSPP) would buy medium- and long-term bonds issued by euro-area governments and institutions. The CSPP would acquire over 11 percent of eligible corporate bonds as of June 7, 2017 (European Central Bank 2017).

***Fed, BOE, and ECB normalization:*** In the spring of 2013, rising employment and PCE inflation near 1.5 percent allowed the FOMC to begin considering removing its unusual accommodation. Unfortunately, Chairman Bernanke's moderately worded efforts to signal this likelihood in May and June 2013 illustrated how central bank communication could roil financial markets. The press labeled the episode the "taper tantrum." After a number of modest reductions, the FOMC ended QE3 on October 29, 2014, but continued reinvesting principal and coupon payments.[47]

From 2015 through 2018, positive economic news allowed the Fed, the BOE, and the ECB to stop accumulating assets and return to conventional short-term interest rate policy. The biggest hiccup in this progression was the turmoil following the U.K. vote on June 23, 2016, to leave the European Union (Brexit). The BOE and BOJ took expansionary measures in Brexit's wake (Bank of England 2016). The FOMC returned to conventional policy in December 2015, while the BOE's Monetary Policy Committee (MPC) returned to conventional tools in November 2017.[48] Finally, somewhat stronger inflation and real growth in 2017-2018 prompted the ECB Governing Council to first reduce and then end its new APP acquisitions in 2018, while describing all moves as being contingent on a path for inflation close to but below 2 percent (European Central Bank 2018).

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[47] Markets were similarly roiled by a March 10, 2016, ECB announcement in which President Draghi announced expansionary policy accompanied by the caveat that the ECB would likely not further ease policy.

[48] The Fed initially planned much-reduced asset holdings, but later revised plans to retain a large balance sheet (Powell 2019). The Fed's long-expected normalization did not significantly move asset prices (Timiraos 2017).

# 4 The effects of unconventional monetary policy on asset markets

This section describes the effects of UMP on financial markets. The first two subsections discuss methods of analyzing UMP effects on financial markets. Subsection 4.3 discusses the research on BOJ UMP in 1999-2006 separately because these methods were distinct from later efforts. Subsections 4.4 through 4.7 discuss research on FG and broad asset purchases, including their effects on asset prices and the channels through which those effects occur. Subsections 4.8 through 4.10 discuss narrow asset purchases, central bank lending support programs, and negative interest rates, respectively.

## 4.1 **Event study methodology**

UMP are heterogeneous, consisting of several types of asset purchases, FG, banking support programs, and negative interest rates. Although there are many ways to evaluate the effects of these disparate programs on financial markets, event studies are very important, particularly for broad asset purchases.

The forward-looking nature of financial markets means that most, or nearly all, of the policy effects on asset prices occur when policy expectations change, rather than when transactions occur.[49] The speed of financial market reactions depends on whether the news is expected, the complexity of the news, and heterogeneity in interpretations. UMP announcements are complex and have sometimes produced reactions that appeared to last for hours or even days.[50] The efficient markets hypothesis implies that an announcement should have its major impact relatively quickly because rational asset pricing and the possibility of arbitrage limits the size of expected changes in asset returns. This should be true for all channels of impact. This logic also implies that an announcement's short-term impact should approximate its longer-term impact.

Because asset prices should react fairly quickly to news about unconventional policy and because this initial reaction approximates the long-term impact, researchers have most often evaluated the effects of unconventional policy on asset prices with "event studies" that examine how asset prices react in a window around some surprising incident. In a standard event study, researchers regress asset returns on an announcement's surprise component as follows:

$$R_t = a + b\ surprise_t + \varepsilon_t, \tag{41}$$

where $R_t$ is the asset's return (or perhaps its volatility) and $surprise_t$ measures the surprise

[49] Event studies may be used regardless of the method by which UMP has its effects, e.g., portfolio balance or expectations of future interest rates or other channel. As soon as some surprising event, such as an official announcement, changes expectations of future fundamentals, arbitrageurs bid asset prices to the level consistent with those expectations, prior to the transactions that change fundamentals. The efficient markets hypothesis rules out the abnormal profit opportunities that would exist if prices did not change until expected transactions were made.

[50] There is greater scope for predictable dynamic reactions when markets are illiquid or highly risk averse.

component of the announcement.[51] For instance, researchers have studied conventional monetary shocks by regressing asset returns on the unexpected change in the federal funds target that is implied by the federal funds futures price changes during an FOMC meeting (Kuttner 2001).

To study the effects of unconventional policy, one would ideally like to know how much a given UMP announcement changed the market's expectation of purchases, i.e., the quantity surprise. That would allow one to estimate the effect of a given purchase on yields. Unfortunately, it is difficult to reliably estimate how much a given announcement changed the market's expectation of the path of purchases, i.e., the quantity surprise.[52]

One can, however, measure an UMP surprise with the post-announcement change in either long yields or the first principal component of the yield curve to estimate the impact of the change in yields on asset returns.[53] That is, one can estimate a regression of the form:

$$\Delta R_t = a + b\ \Delta yields_t + e_t. \tag{42}$$

Such a regression, however, only describes the covariance of long yield changes with asset returns after an UMP shock. It cannot estimate the per-dollar impact of asset purchases.

There is, however, a plausible way—not using regressions—in which one could use event studies to estimate the per-dollar impact of an UMP 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 during those event windows 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. In other words, changes in expectations during the event set sum to the true policy effect.

To illustrate how such assumptions can permit correct estimation of the impact of a QE program, consider an example: A central bank institutes a program in which each $100 billion of long-bond purchases reduces yields by 5 b.p.. Three events change market expectations.

1. The Governor surprises markets by publicly suggesting possible future bond purchases. Expectations of such purchases rise from $0 to $100 billion and long yields fall by 5 b.p..

2. The central bank officially announces a $500 billion purchase program, which raises

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[51] Event studies assume that one can measure the relevant shocks and that other news has negligible effects during the event window. Including expected announcement effects in the regression, rather than just the surprise component, will bias the estimated coefficient toward zero.

[52] Researchers have used the New York Fed's Survey of Primary Dealers (SPD), which is conducted prior to every FOMC meeting (see Correia-Golay, Friedman, and McMorrow 2013) to quantify expectations of forward guidance, the monthly pace of asset purchases, and the System Open Market Account (SOMA), i.e., the Fed's balance sheet. The SPD can also inform policymakers of market participants' views of the efficacy of different strategies—e.g., buying Treasuries vs. MBS. Wu (2014) and Ihrig et al. (2018) have constructed expectations of debt/purchases.

[53] Researchers have commonly used multiple factors to measure monetary policy shocks during conventional periods (Gürkaynak, Sack, and Swanson 2005), but one factor, which is highly correlated with the change in long yields, seems adequate during the unconventional events of 2008-2011 (Wright 2012).

expectations of total purchases from $100 billion to $500 billion and reduces yields by an additional 20 b.p. for a total cumulative drop of 25 b.p..

3. The central bank announces that it is reducing the program's size to $400 billion, expectations of purchases fall to $400 billion, and yields rise by 5 b.p.. The cumulative sum of the yield changes over the three events is 20 b.p..

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 b.p. in terms of yield changes.

This strategy requires researchers to 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 while larger event sets may contain irrelevant events and thus inefficiently estimate the program's effect. Researchers sometimes report results from multiple event sets to allow the reader to see uncertainty associated with such selections.

Because the initial asset purchase programs (i.e., QE1) of the Fed and the BOE were relatively novel in 2008-2009 and markets were unfamiliar with central banks' UMP reaction functions, it is plausible that central bank communications produced all important changes in expectations about the initial asset purchase programs.[54] 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). During later rounds of asset purchases, however, expectations of asset purchases probably changed constantly in response to all sorts of news, making it impossible to estimate the total impact of later QE programs by simply summing announcement effects.

### 4.2 Methods to assess channels of unconventional monetary policy

In addition to studying the effects of UMP asset purchases on long yields, one would like to know through which channels such transactions influence yields to inform policy design and welfare analysis. Researchers typically decompose long yields into the expected average future short rate and the term premium to distinguish between "*signaling*" and "*portfolio balance*" (PB) effects. Signaling directly affects the expected average overnight yield while PB (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.

Researchers decompose long yields with term structure models (TSMs) and swap rates. TSMs are time series models of the stochastic discount factor (SDF) that preclude arbitrage and imply expected time paths for bond yields, the expected future short rate, and (residually) the term premium. The change in those implied paths during UMP event windows is the effect of the UMP. A swap rate is the fixed interest rate that the marginal agent is willing to exchange for

[54] The BOJ had purchased assets in 2001-2006 on a smaller scale and under different circumstances.

floating rate payments. Under risk neutrality, the swap rate is the expected average short-term interest rate over the swap's horizon. Although swap rates surely contain a risk premium, the change in the swap rate at the time of an UMP announcement can estimate the change in the average expected future short-term interest rate if the risk premium changes slowly. The plausibility of this assumption is subject to dispute.

There are no PB effects in standard New Keynesian models, even with financial frictions (Gertler and Karadi 2011; Curdia and Woodford 2011). The only effective tool in such models is signaling about future short-term interest rates (Bhattarai, Eggertsson, and Gafarov 2019). PB theory dates from the work of Tobin (1958, 1969) and was further developed by Brunner and Meltzer (1973) and Friedman (1978). A variety of model features and imperfections—e.g., market segmentation and transaction costs or non-pecuniary benefits of holding bonds of certain maturity—can create PB effects in which yields depend on asset supply (Andrés, López-Salido, and Nelson 2004; Harrison 2012; Chen, Curdia, and Ferrero 2012).

At least two types of risks can produce portfolio rebalancing: "*duration risk"* and "*local scarcity*." Removal of duration from the market can reduce long yields as agents require less compensation to hold the remaining duration risk. The effect should increase monotonically with bond duration. That is, 20-year bond yields should decline by more than 10-year bond yields. A "*local supply*" or "*local scarcity*" effect requires that some agents strongly prefer to hold bonds of certain maturities, perhaps to closely match the maturities of their liabilities. Local supply effects 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.[55]

In addition to signaling and PB effects on riskless yields, UMP might influence spreads between classes of bonds with different characteristics. The "*safety premium*" applies to long-term assets with very low default risk, such as Treasury and agency bonds. Specific client demand for such assets means that changes in the relative supplies of safe/non-safe bonds can differentially affect term premia of investment-grade bonds. Mortgage-backed securities (MBS) are subject to "*prepayment risk*," meaning that the bonds may pay off early if mortgage holders refinance their mortgages, which is likely to happen if long rates fall. Prepayment risk precludes the "*safety premium*" from applying to MBS yields.

One can assess how UMP announcements affect the compensation for types of risk by comparing the reactions of bond prices with different exposure to risk. For example, an UMP announcement that changes the Treasury-MBS spread presumably has changed prepayment or liquidity risk. This is an example of a "differences-in-differences" strategy.

Changes in interest rates through any channel will generally change other asset prices, such as exchange rates, stock prices, and real estate prices. Such asset prices, in turn, will influence consumption and investment.

[55] Culbertson (1957) and Modigliani and Sutch (1966) created local supply models.

### 4.3 **The BOJ's early (1999-2006) quantitative easing and forward guidance policies**

In 1999-2006, the BOJ employed both FG and asset purchases in its attempt to achieve price stability and stimulate the economy. These first modern UMP programs taught valuable lessons to both central bankers and the economists who evaluated them. Researchers introduced methods of analysis, e.g., event studies and TSMs (Bernanke, Reinhart, and Sack 2004), that were to become workhorses for studies of later programs.

***How did the BOJ's policies affect yields and expectations of policy?*** The literature drew mixed conclusions on the effectiveness of BOJ UMP at the ZLB (Ugai 2007). There was some evidence that signaling reduced yields, which Okina and Shiratsuka (2004) termed a "policy duration" effect. Other authors were less sanguine. In a clear precursor to event study and TSM methods used in later UMP studies, Bernanke, Reinhart, and Sack (2004) found only limited evidence that BOJ announcements affected policy expectations. The strongest evidence that BOJ policies reduced yields was that a TSM predicted higher long yields than were actually observed.

***How did the BOJ's actions affect credit spreads and bank lending?*** Bank intermediation is relatively important in the Japanese 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 (Kashyap and Stein 1994). Therefore, one potentially important way that BOJ UMP could have stimulated the Japanese economy is through the availability and cost of funds for banks.

With such channels in mind, researchers have examined BOJ UMP effects on bank stock prices, profitability, and lending. Expansionary QE events systematically raised bank equity prices but raising the purchase ceiling on long-term Japanese government bonds (JGB) purchases had particular impact (Kobayashi, Spiegel, and Yamori 2006). The BOJ QE program also modestly stimulated bank lending, especially for weaker banks, which disproportionately assisted firms doing business with those banks. This success suggests that the weaker banks had been liquidity constrained (Kobayashi, Spiegel, and Yamori 2006; Bowman et al. 2015).[56]

Nevertheless, the BOJ purchases produced some unintended negative consequences. By disproportionately aiding the weakest banks, asset purchases may have encouraged the ever-greening of non-performing loans, significantly prolonging adjustment (Kobayashi, Spiegel, and Yamori 2006). Evergreening, i.e., extending subsidized credit to failing firms (i.e., zombies) to avoid recognizing loan losses, became a serious problem in this period and elsewhere after the financial crisis (Hoshi 2006; Caballero, Hoshi, and Kashyap 2008). Zombie lending tied up capital and workers in failing industries and hindered productive firms by forcing them to compete for workers, customers and bank credit with failing firms.

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[56] Bowman et al. (2015) employ a Kashyap-Stein analysis. To study the bank lending channel of U.S. monetary policy, Kashyap and Stein (2000) use an 18-year quarterly panel of data on U.S. commercial banks to examine how monetary policy affects bank lending as a function of the bank's sensitivity to liquidity constraints.

In addition to perhaps encouraging zombie lending, JGB purchases removed valuable hedges against business cycle risk from the public's portfolio, which reduced high-grade bond yields but raised equity risk premia and credit spreads on low-grade bonds, making risky investment more expensive (Kimura and Small 2006).

***Why were the BOJ's early UMP actions ineffective?*** The BOJ's record with UMP from 1999-2006 appears to be mixed at best. Most notably, the BOJ did not fulfill its pledges to dispel deflation. Two factors probably contributed to the failure: First, policy was inconsistent, which led to poor expectations management. The BOJ failed to tackle deflation in earnest until 1999, although prices had been flat since 1995. The BOJ then first committed to a zero-interest rate policy (ZIRP) in April 1999 "until deflationary concerns are dispelled" before backtracking from the ZIRP in August 2000 and then returning to it in 2001 (Bernanke, Reinhart, and Sack 2004). Similarly, the BOJ prematurely declared victory over deflation in 2006; headline inflation did not exceed 1 percent and core inflation remained negative. Second, the BOJ purchased bonds of relatively short remaining maturity, which reduced the average maturity of the BOJ's portfolio from over five years in 2001 to less than four years in 2005 (McCauley and Ueda 2009). This reduction undercut PB effects and the theorized signaling effects of long-bond purchases (Bhattarai, Eggertsson, and Gafarov 2015). In short, a long period of deflation in the 1990s ingrained deflationary expectations and the BOJ's later stop-and-start measures failed to convince markets that it was able and willing to combat deflation (Ito and Mishkin 2006).

### 4.4 **Forward guidance**

FG is central bank communication about future monetary policy that central banks have used to shape expectations about future short rates in both periods of conventional and unconventional policy. As such, it has greater effects on near- and medium-term rates than on long yields. For this reason, Bernanke (2016) argues that it is a useful complement to unconventional tools, such as negative interest rates, long-rate pegs, and/or asset purchases.

Financial markets have interpreted FG to have both Delphic and Odyssean content.[57] The New York Fed's Survey of Primary Dealers indicates that participants have interpreted some guidance as Delphic, i.e., containing information about employment (Femia, Friedman, and Sack 2013). Conversely, option-implied, risk-neutral distributions for short rates implied that markets interpreted the Fed's early date-based guidance as Odyssean (Raskin 2013). Hubert and Labondance (2018) found evidence that ECB announcements were Odyssean; they persistently lowered the term structure after controlling for the Delphic content.[58]

[57] Cieslak and Schrimpf (2019) use the covariance of asset returns around central bank announcements to define their information content as monetary, growth, or risk news. One might relate monetary shocks to Odyssean FG and growth/risk news to Delphic FG.
[58] Gürkaynak, Sack, and Swanson (2005) pioneered the use of 2-factor models to model the impact of conventional "target" and "path" shocks. The authors interpreted path shocks as resulting from information in FOMC statements. Several papers follow the use of the "path" factor to measure FG, finding that the path factor is correlated with 10-year Treasury yield changes in the wake of the financial crisis (Campbell et al. 2012; Woodford 2012).

Researchers have had difficulty characterizing the economic effects of FG for two reasons: 1) central banks often offer guidance on future short rates simultaneously with other policy announcements, making the marginal effects hard to disentangle. 2) Because FG's effects depend on both the nature of the guidance and existing expectations, they are time varying. Therefore, it is difficult to characterize the effect of guidance even after controlling for its content. For example, the FOMC's promise to keep rates low until "mid-2013" had a much bigger effect than a later promise to keep rates low until "late-2014" (Raskin 2013; Williams 2016; Figure 3).

Swanson (2019) makes an econometrically sophisticated effort to disentangle the separate effects of conventional policy, FG, and asset purchase announcements with a 3-factor model. FG has more influence on short-term yields and stock prices while purchase announcements have greater effects on long-term yields. Using methods very similar to those of Swanson (2019), Altavilla et al. (2019) also disentangle monetary policy shocks, finding persistent effects of FG.

Because it is difficult to separately identify the effects of simultaneously announced policies, almost all FG studies have either jointly evaluated the effects of FG and other policies or considered case studies in which FG was the only important news. Therefore, the next subsection describes research that (mostly) jointly evaluates asset purchases and FG.

### 4.5 Broad asset purchase and forward guidance effects on asset prices

***What effect did broad purchases and forward guidance have on yields?*** Although all four major central banks eventually engaged in broad asset purchases after the financial crisis, the Fed and BOE were the first to do so and most research on such policies has focused on those of the Fed, especially the earliest efforts in 2008-2009. These have been regarded as among the most important UMP operations and have received the lion's share of study partly because the novelty of QE1 offered researchers an opportunity to infer the per-dollar effect of asset purchases from a plausibly defined set of events, as discussed in Subsection 4.1.[59]

Event studies clearly show that the Fed large-scale asset purchase (LSAP) announcements in 2008-2009 substantially reduced U.S. long-term yields for a variety of bonds (see Gagnon et al. 2011; Krishnamurthy and Vissing-Jorgensen 2011, henceforth KVJ). Table 1, which is reproduced from Gagnon et al. (2011), shows that both small ("baseline") and large ("baseline + all FOMC") event sets imply very substantial yield and premia changes during the event sets. The 10-year Treasury yield fell by 91 b.p. over the baseline event set and 55 b.p. over the "all event" set. One interpretation of the disparity between event sets is that FOMC events in the "all event" set that were not also in the baseline set reduced expectations of further QE (Greenlaw et al. 2018).

[Table 1 here]

[59] Researchers studying QE1 often assume that it was (almost) entirely unanticipated, but McInish, Neely, and Planchon (2019) 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.

Yields of 10-year Agency bonds and 30-year Agency-backed MBS fell by even more than the Treasury yield—156 and 113 b.p. over the baseline events, respectively—suggesting reduced default and prepayment risk as well. Consistent with reduced prepayment risk, mortgage rates declined by about 100 b.p. (Hancock and Passmore 2011).[60] These early Fed announcements also raised market measures of inflation expectations (breakeven inflation) substantially, which lowered ex ante, real, long-term yields and presumably stimulated consumption and investment (Guidolin and Neely 2010; Farmer 2012, 2013). The literature too often overlooks UMP's impact on expected inflation.

The 2009-2010 BOE asset purchases had long yield effects similar to those of the Fed's QE1 (Gagnon et al. 2011).[61] Event set reactions to monetary policy events suggest that these announcements reduced gilt yields by about 100 b.p., which Joyce, Tong, and Woods (2011) equate to a 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.

The ECB engaged in a broad asset purchase program broadly similar to those of the Fed and BOE. Although ECB bank lending programs, negative interest rates and expectations of asset purchases had already pushed down Euro yields, De Santis (2020) finds that the ECB program reduced yields by about 70 b.p., comparable to estimates for Fed and BOE asset purchases. Altavilla, Carboni, and Motto (2015) estimate lower effects on yields, in the 30-50 b.p. range, with even greater effects on high-yield bonds, such as those of Italy and Spain. The authors also find considerable spillovers to corporate bonds, despite relative financial calm. Both papers used the intensity of news coverage to identify important events.

***How did broad asset purchases affect international asset prices?*** In addition to reducing domestic yields, UMP reduced international yields and depreciated domestic currencies. Fed QE1 announcements reduced developed country sovereign bond yields by about 40 percent as much as U.S. yields (Neely 2015). The top panel of Figure 4 illustrates large changes in futures prices on international bonds after the March 18, 2009 QE1 purchase announcement.

[Figure 4 here]

Broad asset purchase announcements also depreciated the domestic currency. Fed and BOE QE1 announcements reduced the foreign exchange value of the USD and GBP by 6 to 10 percent and 4 percent respectively, (Neely 2015; Joyce et al. 2011). Figure 4, middle panel, illustrates the exchange rate reaction to the March 18, 2009 Fed announcement. Likewise, the BOJ's 'Abenomics' announcements and the ECB's APP announcement reduced the value of the JPY

[60] Stroebel and Taylor (2012) find little effect of the MBS purchase program on the option-adjusted, MBS-LIBOR spread (OAS). But this dependent variable removes the compensation for prepayment risk and the authors further control for changes in default risk, leaving only duration risk to be influenced by MBS purchases. It is therefore unsurprising that Fed purchases can only have a very modest effect on the residual OAS.

[61] Both the Fed's QE1 and the first set of BOE asset purchases (2009-2010) purchased bonds valued at about 11-14 percent of their respective nominal GDPs.

and EUR (Fukuda 2015; Georgiadis and Gräb 2016).

Fed announcements produce qualitatively similar but less uniform effects on emerging market yields and exchange rates (Bowman, Londono, and Sapriza 2015). The effects are often not statistically significant unless one permits delayed effects —for days or weeks—and the multiplicity of tests gives reason for concern about significance levels. Riskier emerging markets respond more strongly to U.S. policy, perhaps because of exposure to international conditions.

***Can a central bank in a small open economy affect yields with asset purchases?*** Central banks in small open economies have also reduced yields by bond purchase announcements. The March 12, 2009 SNB bond purchase announcement lessened the term premium for mortgage-backed covered bonds by 10 b.p., which Kettemann and Krogstrup (2014) attribute to a PB effect (Tobin 1958, 1969; Hamilton and Wu 2012; Vayanos and Vila 2009).[62] Similarly, in 2015-2016, the Riksbank announced bond purchases that lowered Swedish long yields by 46 b.p. through PB effects (De Rezende 2017).

***How does quantity-of-debt affect yields at low frequencies?*** Researchers have studied the low-frequency relation between yields and measures of debt to complement or substitute for event study evidence. These studies broadly corroborate the claims that changes in the quantity and/or maturity structure of publicly held debt produced the event-study yield changes. The Vayanos and Vila (2009) segmented markets model typically motivates and informs such studies.

An initial group of such low frequency regression studies estimated the impact of changes in debt or maturity structure on yields, term premia or credit spreads (Gagnon et al. 2011; KVJ; Chadha, Turner, and Zampolli 2013). For example, the second part of Gagnon et al. (2011) uses monthly data on net government bond supplies — net of Fed and foreign official holdings — and control variables ($X_t$) to explain the Kim-Wright 10 year term premium ($TP_t^{KW}$) and the 10-year Treasury yield. Such a regression can be written as follows:

$$TP_t^{KW} = a + b * bond\ supply_t + c * X_t + e_t. \tag{43}$$

The highly significant coefficients on the bond-supply regressors imply that the Fed's QE1 reduced the duration-adjusted 10-year Treasury yield and term premium by 58 and 38 b.p., respectively.[63] These estimates are consistent with their event study estimates. Such a regression may produce endogeneity bias as governments issue more overall debt or more long-term debt when long rates are low. To combat such endogeneity bias, KVJ use total-debt-to-GDP as an instrument for the maturity weighed debt-to-GDP to explain corporate-Treasury spreads.[64]

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[62] The covered bond spread is the difference between the yields of a covered bond and a Swiss Confederation bond with the same maturity. The actions of the Fed and the BOJ on March 18, 2009 might have affected Swiss yields.
[63] Thornton (2014) argues that inference in some (but not all) quantity-of-debt regressions is sensitive to the treatment of a time trend. That is, bond supplies do not affect yields in some models if one treats trends properly.
[64] 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.

While the above papers use the Vayanos-Vila (2009) segmented markets model informally to motivate regressions, Greenwood and Vayanos (2014) and Altavilla, Carboni, and Motto (2015) construct formal TSMs with Vayanos-Vila (2009) structural features to inform predictions for similar low-frequency regressions. Eschewing regressions altogether, Hamilton and Wu (2012) formulate and estimate a structural TSM with Vayanos-Vila (2009) features and calculate the effect of a change in debt structure on the term structure of interest rates.

These models of the relation of yields (or spreads) to bond supply variables are subject to the criticism that financial markets are forward looking and variation in the level of government debt is fairly predictable, so yields should change long before quantities change. Wu (2014) and Ihrig et al. (2018) confront this problem in similar ways. Using forward-looking market projections of the magnitude and duration of the Fed's asset purchases in a regression model, Wu (2014) estimates that Fed asset purchases have lowered the 10-year term premium by 100 b.p.. Ihrig et al. (2018) estimate a TSM in which bond supply factors evolve consistently with market expectations. This procedure implies that Fed events collectively had reduced the 10-year term premium by 100 b.p. with a 90 percent confidence range from 56 to 144 b.p., as of 2015Q1.

One should be cautious in generalizing about the conclusions of such papers as their dependent variables range from yields to term premia to credit spreads, and they use several different measures of debt, from the average maturity of debt to the quantity of debt of a certain maturity as a percentage of GDP. Indeed, the variation in debt measures raises the fundamental question about the definition of debt: Should one count government-guaranteed debt, such as agency MBS, or high-grade corporate debt that are close substitutes for sovereign debt?

Generally, these low-frequency papers find effects of asset purchases that are near or below the lower point estimates from event studies but still sizable. Given the uncertainty associated with both sets of estimates, one might say that the low-frequency estimates are consistent with the range of estimates from event studies. More structural papers, such as Hamilton and Wu (2012) and Greenwood and Vayanos (2014), tend to find lower effects than regression studies.

Quantity-of-debt studies likely understate the impact of asset purchases because they ignore signaling effects, which likely create part of the impact of UMP announcements. A second reason may be that event studies focus on QE1—a period of heightened risk—while the low-frequency studies measure long-run effects. Periods of heightened risk might produce greater demand for safe assets and larger risk premia effects (KVJ).

***How did broad asset purchases affect equity prices?*** In addition to its effect through yields, expansionary monetary policy is often thought to influence economic activity by raising stock prices and improving balance sheets (Tobin 1969; Ehrmann and Fratzscher 2004). Such equity price increases can raise consumption through the wealth effect, increase investment through Tobin's *q* and alleviate asymmetric information problems in lending markets. In addition, lower interest rates reduce payments on variable rate debt — the "floating rate channel" — which strengthens firms' cash flows and balance sheets (Ippolito, Ozdagli and Perez-Orive 2018).

Unusually, U.K. stock markets reacted somewhat differently to the first rounds of BOE UMP announcements than did U.S. equity markets to Fed announcements. Fed QE1 announcements that strongly reduced U.S. long yields only modestly increased U.S. equity indices (Wright 2012). The bottom panel of Figure 4 shows a modest stock futures price response of around 1 to 2 percent. The first rounds of BOE announcements had inconsistent and overall negative effects on equity indices (Joyce et al. 2011).[65] ECB UMP announcements significantly and persistently boosted global and euro-area equities (Georgiadis and Gräb 2016; Altavilla et al. 2019). Foreign investors drove strong, positive stock market reactions to 'Abenomics' announcements (Fukuda 2015). In all, expansionary UMP announcements often clearly raised equity prices, but the effects may not have been as large as the reactions to conventional shocks would suggest.

There are reasons to believe, however, that a UMP shock might not affect stocks and other assets in the same way as a conventional policy shock (Woodford 2012), and such an attenuated reaction would imply less stimulus for UMP (Fuhrer and Olivei 2011). To investigate the surprisingly modest impact of UMP-associated yield changes on equity prices, Kiley (2014) considers a system in which the true monetary policy shock is unobserved and he therefore estimates a 2-equation, instrumental variables system using short yields as instruments for the long-yield policy variable. Kiley argues that UMP had modest effects on equities because such shocks moved only the medium and long ends of the yield curve, not the whole curve.

The fact that unconventional shocks don't move the short end of the yield curve means that UMP won't reduce floating rate debt payments of firms that have such debt. That is, the "floating rate channel" doesn't function when short rates are very near zero (Ippolito, Ozdagli, and Perez-Orive 2018). This provides another reason for a weak effect of UMP on stock prices.

The limited effect of asset purchase announcements on equities might have another, complementary explanation: delayed impact from rational inattention (Mamaysky 2018). The author argues that equity prices exhibit delayed responses to Fed, BOE, and ECB monetary announcements. The procedure employs a bootstrap to correct critical values in searching for significant responses over multiple horizons.

The effects of Fed UMP on bank stock prices may have been particularly important. Chodorow-Reich (2014) establishes that Fed UMP announcements from 2008-2013 raised bank stock prices, recapitalizing banks as in the model of Brunnermeier and Sannikov (2016), and thereby reduced the banks' incentives to make excessively risky loans or disguise losses. Consistent with this, the announcements also reduced banks' credit default swap (CDS) rates.

***How do conventional and unconventional monetary effects on asset prices differ?*** Wright (2012) established that UMP shocks had weaker effects on stock prices than previous studies of conventional shocks would suggest. This raises the question as to how to measure conventional

[65] Farmer (2012, 2013) argues that, because MBS payoffs are procyclical, their returns should be correlated with equity returns and that the Fed's MBS purchases were closely tied to stock price variation.

and unconventional shocks and how to compare their impacts on asset prices. Conventional monetary policy shocks are measured with short-term rates while UMP shocks mainly move medium and long rates.[66] To directly compare the impact of conventional and unconventional shocks, it would be useful to measure such shocks through their effects on a common spectrum of asset prices. Two recent papers have employed multiple assets in examining the effects of conventional and UMP on asset prices but have reached different conclusions.[67] Claus, Claus, and Krippner (2018) estimate a latent factor model on six assets over subsamples, identifying the monetary shocks through heteroskedasticity. The estimation implies that UMP shocks are larger than conventional shocks and that the six assets' prices are more sensitive to such shocks.[68] In contrast, Inoue and Rossi (2018) model monetary shocks as a shift in the whole yield curve, which they call a "functional shock." Both the sign and magnitude of UMP effects on exchange rates are similar to those of conventional monetary policy, and there is even evidence of the venerable Dornbusch (1976) "overshooting" effect on exchange rates.

### 4.6 **Channels of broad asset purchase and forward guidance effects on asset prices**

The channels through which asset purchases affect bond yields is important for program design and welfare analysis. As discussed in Subsection 4.2, the most basic decomposition of channels is into their effects on expected short-term interest rates and term premia, which are associated with signaling and PB effects, respectively.[69] Duration and local supply effects should be the major effects on riskless term premia, with the former affecting the longest maturities and the latter affecting prices of securities with the closest maturity to those purchased (Tobin 1958, 1969; Modigliani and Sutch 1966). In addition to those channels, certain factors—default risk, prepayment risk, safety—influence spreads between types of bonds, producing cross-sectional effects.[70]

Researchers have used three main methods to evaluate the channels through which QE and FG affect yields: 1) event studies comparing yield changes, with or without TSMs; 2) micro studies of local supply effects; and 3) differences-in-differences comparisons of yields of different types of bonds.

***What do event studies indicate about the channels of UMP?*** Many event studies have used an informal differences-in-differences method to judge the relative importance of signaling vs. PB effects by comparing reactions of short- and medium-term yields to surprising UMP events. Using such reasoning, both Gagnon et al. (2011) and Joyce et al. (2011) interpret the evidence to

[66] Fawley and Neely (2014) survey the literature on the impact of Fed conventional policies on asset prices.
[67] The Wu and Xia (2016) shadow rate framework might be used to compare conventional and UMP.
[68] Kiley (2016) shows reduced Treasury-corporate pass-through in the unconventional period. Although a safety channel could potentially be driving this change, Kiley notes that his analysis does not support a particular channel.
[69] Woodford (2012) discusses the theory of signaling effects on short-term interest rates. Designating expected short rate effects as signaling and term premia changes as portfolio balance effects is only approximate. For example, a portfolio balance effect on term premia can also influence expected short rates through its effect on expected growth, while a decline in expected short rates can also affect term premia through default risk.
[70] See Section 2 (Gertler and Karadi 2011, 2013; Gertler and Kiyotaki 2010).

favor large PB effects, rather than signaling, for the price impacts of the initial U.S. and U.K. asset purchase programs (2008-2010). Both papers cited the PB framework of Tobin (1958) among other theoretical papers, which Section 2 discusses.[71] Modest signaling effects from early BOE announcements is consistent with the absence of explicit FG from such events (Joyce et al. 2011; Williams 2016).

Event studies and complementary differences-in-differences methods also revealed information about the channels by which different types of asset purchases worked. The Fed's MBS purchase program reduced MBS yields and the mortgage-Treasury spread substantially through improved market functioning, clearer government backing for Fannie and Freddie and portfolio-balance effects on yields (Hancock and Passmore 2011). Fed MBS purchases had a greater effect on MBS yields and mortgage rates relative to Treasury acquisitions through the prepayment channel (KVJ). Consistent with that, micro data revealed that Fed MBS purchases—but not Treasury purchases—reduced conforming mortgage rates significantly more than non-conforming rates (Di Maggio, Kermani, and Palmer 2020).[72]

***What do term-structure models indicate about the channels of UMP?*** Several sets of researchers have combined TSMs with event studies to assess the relative importance of the signaling and PB effects. While TSMs typically imply substantial impacts from both PB and signaling, they differ on which effect dominates. TSMs that correct for small-sample bias in estimating the persistence of the time series process of the yield curve factors, i.e., Bauer and Rudebusch (2014) and Christensen and Rudebusch (2012), tend to estimate larger signaling effects than other papers, i.e., Gagnon et al. (2011), because greater persistence in the level of the yield curve implies that a given shock will change expected short rates for a longer period. Despite using a bias-corrected TSM, however, Christensen and Rudebusch (2012) attribute the entire decline in U.K. QE1 10-year yields to a lower term premium, in sharp contrast to their U.S. results. The lack of signaling is consistent with Joyce et al.'s (2011) estimates and with the BOE's eschewal of FG prior to 2013.

Intriguingly, Christensen and Rudebusch (2012) find that BOE QE1 announcements actually boosted expected future U.K. short-term interest rates, probably by raising expected growth. Such "negative" signaling effects exemplify the tendency of TSMs to overstate term premia effects and understate expected short rate effects. Changes in expected short rates should be viewed as conservative estimates of signaling because asset purchases that successfully reduce term premia will also raise expected growth and therefore expected future short rates. This will produce an apparently negative "signaling" effect (Bauer and Rudebusch 2014; Christensen and

[71] Gagnon et al. (2011) did not interpret large declines in 10-year swap rates as "signaling" effects over concerns that risk premia changes had produced the declines; Joyce et al. (2011) cite modest overnight index swap (OIS) declines as evidence of modest signaling, which they also term the macro/policy news channel and/or expectations. The Gagnon et al. (2011) view implicitly acknowledges that an UMP announcement may change the market's expected rate of return, which will affect the current price.
[72] Conforming mortgages follow GSE purchase guidelines. The total loan value of each conforming mortgage is capped and the loan-to-value ratio must be less than 80 percent. The Fed purchased only conforming MBS.

Rudebusch 2012; Bauer and Neely 2014; Hattori, Schrimpf, and Sushko 2016).

Bauer and Neely (2014) use several TSMs to show the relative importance of signaling versus PB channels in spillovers of U.S. UMP shocks to international yields. UMP shocks produced large signaling effects in bonds whose yields were ordinarily sensitive to conventional U.S. monetary policy, such as those of Canada. Likewise, bonds whose returns historically covary strongly with U.S. bond returns, such as those of Australia and Germany, exhibited large PB effects from Fed UMP shocks.

Model and sampling uncertainty associated with TSM calculations are important but underemphasized issues in this TSM literature. Many of the apparent inconsistencies in estimates of signaling and PB effects might well disappear or at least be minimized if researchers reported the uncertainty associated with such estimates. Bauer and Neely (2014), for example, illustrate the sensitivity to model uncertainty by showing estimates from five specifications.

***How do term-structure models cope with the ELB?*** Researchers use TSMs to ascribe the relative importance of signaling and PB effects in UMP, but typical TSMs counterfactually allow interest rates to become negative without discontinuity in behavior. Following the theory of Black (1995), researchers have developed specialized shadow rate TSMs to measure the stance of monetary policy when the traditional monetary policy instrument nears the ZLB. Such models forecast short rates more accurately than conventional TSMs and provide formal measures that accord with intuition (Krippner 2013a, 2013b; Wu and Xia 2016; Bauer and Rudebusch 2016). For example, the estimated U.S. shadow rate in Krippner's (2013b) model became negative near the first Fed QE announcement in November 2008, decreased further in August 2010 when Chairman Bernanke hinted at further asset purchases by the Fed, and increased during the 2013 "taper tantrum." Wu and Xia (2016) have used shadow rate models in factor-augmented VAR (FAVARs) and event studies to confirm that the shadow rate covaries strongly with asset purchase expectations.

The introduction of negative deposit rates in the euro area and Japan brought about the need to modify shadow rate TSMs to use a time-varying ELB. Such modifications improve the models' fit and provide practical estimates of quantities of interest (Lemke and Vladu 2017; Kortela 2016). The addition of latent state variables for immediate and future monetary policy allowed Wu and Xia (2019) to interpret most market reactions to the ECB's NIRP measures as indicating more accommodation rather than bad economic news.

***How important are local supply effects on yields?*** Motivated by preferred habitat models, such as those of Andrés, López-Salido, and Nelson (2004) and Vayanos and Vila (2009), local supply models predict that bond purchases will have larger effects on returns or yields of bonds with maturities most similar to those of the purchased bonds. To examine local supply effects of a program or set of announcements, researchers compare the cross-section of returns on all individual bond issues (CUSIPs) over a purchase program to the distribution of central bank purchases by maturity, usually with control variables.

Fed and BOE asset purchases had substantial local supply effects. Averaging across five Fed events, Cahill et al. (2013) find that a $100 billion surprise Fed purchase reduces yields by 5 b.p. from the duration-risk effect and 4 b.p. from the local-supply effect.[73] These effects are about twice as large as event study findings. Similarly, McLaren, Banerjee, and Latto (2014) estimated consistently large local supply effects of BOE purchase announcements, which accounted for about half of the total impact on gilt yields. This impact is passed through to index-linked gilt and investment grade corporate yields. The local supply impact of purchases has not declined over time after one controls for pre-announcement expectations (Cahill et al. 2013; Joyce, McLaren, and Young 2012).

Cahill et al. (2013) and McLaren, Banerjee, and Latto (2014) pursue similar strategies to construct the surprise component by maturity of the respective Fed and BOE announcements. Cahill et al. (2013) use the Survey of Primary Dealers, information from primary dealer market commentaries, and announcement details about the intended distribution of purchases/sales across maturity sectors. McLaren, Banerjee, and Latto (2014) use a Reuters survey of private-sector economists to estimate expected purchases across maturities.

***Is there a reserves channel of asset purchases?*** In early August 2011, the SNB announced a plan to raise bank reserves by purchasing SNB short-term bills with the funding coming entirely from foreign exchange swaps. Such transactions should have produced no traditional PB or signaling effect because they did not reduce the duration of publicly held securities or remove long bonds from the market; it was an exchange of short-term instruments. Bernanke and Reinhart (2004), however, had suggested that reserves expansion could produce a PB effect because only banks hold reserves and so banks must rebalance their portfolios if reserves change. Using TSM/event study methods, Christensen and Krogstrup (2019) confirmed this Bernanke and Reinhart (2004) PB effect: The SNB reserve expansion substantially reduced long rates (28 b.p.) with no appreciable signaling. This argues that the quantity of reserves may be an important policy tool, even without a change in duration or quantity of long bonds, although the BOJ experience in 2001-2006 seems to suggest otherwise.

***Did broad asset purchases reduce yields by raising perceived macro risk?*** Some analysts argue that central bank asset purchase announcements sharply reduced bond yields by raising the perceived risk for the macroeconomy. This argument is inconsistent with how options on equities responded to UMP announcements that reduced near-term option-implied tail risk—the risk-neutral-implied probability of extreme events—in equity and interest rate markets. There was no effect on equity volatility, i.e., VIX, however (Hattori, Schrimpf and Sushko 2016). As the authors note, this decline in tail risk is consistent with the argument of Brunnermeier and Sannikov (2012) that central bank asset purchases can insure against tail events and broadly reduced default risk (i.e., CDS rates) for both investment and speculative grade bonds from Fed

[73] Early local supply studies estimated fairly large effects from raw purchases, which may have approximated surprises, given the novelty of the early Fed and BOE purchases. D'Amico and King (2013), for example, estimated that $300 billion of Treasury purchases reduced yields 30 b.p. across the curve with 50 b.p. at longer maturities.

QE1 announcements (Gilchrist and Zakrajšek 2013). But the latter authors find no evidence that the announcements specifically decreased financial sector default risk. In summary, UMP seemed to reduce perceptions of macro risk, not increase them.[74]

***How did the type of purchased asset influence bond spreads?*** KVJ argue that MBS purchases have the most impact on non-sovereign markets because they affected MBS yields through the "mortgage prepayment risk" channel, and mortgage rates through the "safety channel."[75] KVJ also argue that QE1 reduced yields of high-yield bonds through default risk.[76]

### 4.7 **Broad asset purchase and forward guidance effects on loans and portfolio choice**

The previous subsection established that UMP had large effects on asset prices/bond yields. But to affect economic activity, such price/yield changes must induce changes in quantities, i.e., portfolio rebalancing, loan activity, and bond issuance. Examining such changes in quantities can tell us about how purchases affect the economy.

***What were the effects on mortgage applications, refinancing, and originations?*** All Fed asset purchase programs raised mortgage originations, but Treasuries and MBS purchases had different cross-sectional effects. Purchases of MBS raised conforming mortgage originations much more than non-conforming and the Fed's QE disproportionately benefited consumers eligible for a conforming mortgage (Di Maggio, Kermani, and Palmer 2020).[77] The authors estimate that QE1 increased refinancing by $102 billion in the first six months, which increased consumption by $13.5 billion through lower mortgage costs. These authors connect their work to market segmentation theory: Cúrdia and Woodford (2011); Brunnermeier and Sannikov (2016); Drechsler, Savov, and Schnabl (2017); Del Negro et al. (2017); Gertler and Karadi (2011); Greenwood, Hanson, and Liao (2018); and Farmer and Zabczyk (2016).

***How did asset purchases influence portfolio rebalancing?*** Heterogeneous portfolio rebalancing after Fed, BOE, and ECB asset purchases supports market segmentation theories. Net sellers of bonds purchased by the Fed and BOE rebalanced into riskier debt instruments but not equity (Carpenter et al. 2015; Joyce, Liu, and Tonks 2017). The ECB's PSPP prompted similar rebalancing toward longer maturities and bonds issued by non-euro-area banks (Bua and Dunne 2019). BOJ asset purchases also led to significant but heterogeneous changes in the portfolios of Japanese regional banks. In Japan, only large banks with low non-performing loan ratios—i.e., the safest banks—saw deposit growth after QE, which suggests discerning depositors (Matousek

[74] The post-announcement increase in equity and oil prices in the bottom panel of Figure 4 is consistent with the interpretation that the announcement increased expected growth.
[75] Gabaix, Krishnamurthy, and Vigneron (2007) provide a theory of prepayment risk premia.
[76] KVJ argue against an important duration risk channel because there was no evidence of a monotonic impact of maturities on yield changes. We think that KVJ may have dismissed the duration risk channel too quickly because local supply effects—which were not considered in KVJ—could have masked duration effects.
[77] Fuster and Willen (2010) study the loan market responses to QE1 with micro data: The November 25, 2008, announcement of the Fed's MBS purchases increased household searches, applications, and acceptances in the primary loan market. Such increases persisted and peaked again after the big March 18, 2009, QE1 announcement.

et al. 2019). Overall, the heterogeneous rebalancing by agent type and the move toward riskier debt, rather than equities, is consistent with preferred habitat theories of Vayanos and Vila (2009) and Li and Wei (2013).

Perhaps predictably, the lower international yields from U.S. UMP substantially increased international corporate bond issuance, especially in emerging markets, even after controlling for weakness in the international banking sector (Lo Duca, Nicoletti, and Martínez 2016).

But rebalancing does not always occur in a predictable way. For example, foreign investors sold purchase-eligible bonds in response to ECB asset purchases. Such sales by foreign investors is surprising because 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 (Koijen et al. 2017).

***Did the type of asset purchase affect loan quantities and characteristics?*** A bank's MBS holdings affect the response of its lending to MBS purchases. Financial institutions with relatively larger MBS holdings expanded lending after the Fed's QE1 and QE3, but not after QE2, which purchased only Treasuries (Rodnyansky and Darmouni 2017).[78] QE1 and QE3 reduced banks' lending standards and each round raised loans as much as a 1 percentage point decrease in the fed funds target (Kurtzman, Luck, and Zimmermann, forthcoming). The increased mortgage lending crowded out Commercial & Industrial (C&I) lending.[79] Firms associated with these high-MBS exposed banks reduced their investment following QE1 and QE3 (Chakraborty, Goldstein, and MacKinlay 2020).

Although the BOE's MPC did not expect that its long-maturity bond purchases would raise bank lending, this was certainly possible. Researchers find little evidence for such a channel, however. Adapting the theoretical model of Kashyap and Stein (1994), Joyce and Spaltro (2014) find support for a marginal bank lending channel, which functions better for smaller and better capitalized banks and/or those with less access to external funding. In contrast, Butt et al. (2015) use a monthly, confidential BOE dataset to challenge the idea that banks that received QE deposits expanded lending more than those that did not.

***How did asset purchases influence international asset flows?*** Asset purchases might well also prompt international rebalancing. Major central bank unconventional asset purchases influenced gross financial inflows to emerging markets, although the effects depended on both the type of asset flow and economic conditions (Lim and Mohapatra 2016; Bowman, Londono, and Sapriza 2015).[80] While the volatile conditions of 2009 (QE1) induced international investors to rebalance toward riskier assets, i.e., mostly U.S. equities, asset purchase announcements in the more

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[78] U.S. banks hold few Treasuries, so purchases of such securities should not necessarily affect banks differently.
[79] Rodnyansky and Darmouni (2017) did not find such crowding out, a fact that Chakraborty, Goldstein, and MacKinlay (2020) attribute to Rodnyansky and Darmouni's (2017) use of timing alone to identify changes in bank behavior. Use of timing along conflates the effect of QE with other policy changes.
[80] Lim and Mohapatra (2016) cite a large theoretical literature on spillover effects: Betts and Devereux (2000, 2004), Fukuda (1993), Obstfeld and Rogoff (1995), and Turnovsky (1986).

tranquil environments of the Fed's QE2 and QE3 triggered flows to EMEs (Fratzscher, Lo Duca, and Straub 2018). Financial flows (particularly fixed income) were more sensitive to asset purchases than foreign direct investment (Lim and Mohapatra 2016; Fratzscher, Lo Duca, and Straub 2018), in line with the capital flow literature, e.g., Frankel and Rose (1996).

### 4.8 **How did narrow asset purchases affect asset prices, volatility and capital flows?**

The ECB conducted the SMP and OMT programs for limited purposes: to repair sovereign debt market functioning, not to provide general stimulus. A key issue in the study of the SMP program is that the ECB purchased securities on an "as-needed" basis. That is, the program's size and pace depended on market conditions, which means researchers must confront significant simultaneity/endogeneity problems to differentiate the determinants of SMP purchases from their effects. An additional complication is the fact that SMP purchase data were publicly available only at a weekly frequency, although ECB researchers had access to confidential intraday data.

***How did the SMP/OMT affect yields and volatility?*** Despite disagreement over the treatment of simultaneity/endogeneity in studying the SMP, three groups of researchers came to similar conclusions about its effects: SMP announcements broadly reduced sovereign yields (especially in smaller and more stressed markets), bond volatility, kurtosis, and tail risk (Eser and Schwaab 2016; Ghysels et al. 2017; Fratzscher, Lo Duca, and Straub 2016).[81] Greek yields were an exception, which underscores the need for fiscal sustainability (Ghysels et al. 2017).

Despite their reduction of euro periphery bond yields, the LTROs, SMP, and OMT had no significant international spillovers on yields or portfolio flows (Fratzscher, Lo Duca, and Straub 2016). The lack of such spillovers contrasts with those of Fed QE on international yields (Subsection 4.5; Neely 2015) and capital flows (Subsection 4.7; Fratzscher, Lo Duca, and Straub 2018).[82] Fratzscher, Lo Duca, and Straub (2016) conjecture that the dollar's global role or the post-crisis shrinkage in the relative importance of banking vs. bonds might explain this disparity.

Consistent with the ECB's intention to use the narrow purchases to remedy dysfunctional markets, lower default and liquidity risk drove much of the reductions in yields (Eser and Schwaab 2016; Krishnamurthy, Nagel, and Vissing-Jorgensen 2017).[83] The SMP/OMT programs also lessened the perceived risk that Italy, Spain, and Portugal would default by redenominating their debt in a new local currency (Krishnamurthy, Nagel, and Vissing-

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[81] Eser and Schwaab (2016) argue that coordination within the Eurosystem required purchase decisions and amounts to be predetermined each day. Both Ghysels et al. (2017) and Fratzscher, Lo Duca, and Straub (2016) dispute the predetermination assumption, arguing that simultaneity problems exist at the daily (or lower) frequency.
Eser and Schwaab (2016) cite the theory of De Pooter, Martin, and Pruitt (2018), Pasquariello, Roush, and Vega (2020), Greenwood and Vayanos (2010), and Corsetti and Dedola (2016) as rationalizing price effects from recurring central bank bond market purchases on grounds ranging from search-theory, to local supply, to signaling.
[82] Although Ghysels et al. (2017) find that the SMP reaction function is ill defined at high frequencies, this may not affect Fratzscher, Lo Duca, and Straub's (2016) identification, which hinges on a lower-frequency reaction function.
[83] Krishnamurthy, Nagel, and Vissing-Jorgensen (2017) cite Aguiar and Amador (2014) on determinants of sovereign bond yields.

Jorgensen 2017).

***Did the SMP/OMT simply transfer risk?*** By purchasing the debt of fiscally extended countries, the SMP transferred risk from crisis to non-crisis countries, thus lowering (raising) the yields of the former (latter). The OMT was less likely to transfer such risk as it included provisions for countries in need of purchases to plan for fiscal reform. Consistent with this, the OMT reduced spreads for both crisis and non-crisis countries and thus created an incentive for member states to issue more short-term debt, which they did (Jäger and Grigoriadis 2017).[84]

Although the SMP transferred risk from the core to the periphery, it was not just a transfer. The SMP/OMT raised equity prices and lowered volatility throughout the euro area, suggesting there were common gains from higher confidence or less risk aversion (Fratzscher, Lo Duca, and Straub 2016; Krishnamurthy, Nagel, and Vissing-Jorgensen 2017).

Researchers evaluated the SMP/OMT with caution. 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, while Fratzscher, Lo Duca, and Straub (2016) carefully remain agnostic as to whether the SMP was an effective tool.

### 4.9 How did support programs affect the banking system?

As discussed in Section 3, the ECB, BOE, and BOJ supported bank lending with incentive programs, such as the BOJ's SBLF, the ECB's TLTROs and the BOE's FLS and TFS. In addition, some ECB asset purchase programs similarly supported bank lending. Much of the research on banking-support policies focused on the varied and aggressive ECB programs.

In 2007-2010, the ECB perceived that widely varying financial conditions in the euro zone impaired the usual bank lending channels of monetary policy. After having only modest success with elastic liquidity provision to banks, the ECB turned to more aggressive measures: 3-year LTROs, a 0 percent deposit rate, the SMP, the OMT, CBPP1 and CBPP2. These mostly normalized heterogeneous lending conditions and reduced borrowing costs, especially for high-risk countries (Beirne et al. 2011; Szczerbowicz 2015; Altavilla, Canova, and Ciccarelli 2020). The asset purchase effects spilled across euro-area markets. Covered bond purchases reduced sovereign yields and the SMP/OMT reduced covered spreads even more than the covered bond purchases (Szczerbowicz 2015). The CBPP even broadened the covered bond market by encouraging institutions in smaller markets to use it for funding (Beirne et al. 2011).

The ECB's banking support programs particularly helped banks with low capital ratios and high non-performing loan ratios. Bank characteristics—capital ratio, exposure to sovereign debt, and non-performing loan ratio—rather than bank location (periphery vs. center) determined how well all monetary policies passed through (Altavilla, Canova, and Ciccarelli 2020).

Despite their success in normalizing financial conditions, these banking support programs had

[84] Jäger and Grigoriadis (2017) also found that LTROs caused non-crisis countries to increase their debt issuance.

unintended consequences. First, the bank lending programs created the conditions for a carry trade in which Portuguese, Italian, and Spanish banks borrowed from the 3-year LTRO to buy government securities, which they then used as collateral to borrow more reserves, matching the maturities of the bonds and loans to avoid risk (Crosignani, Faria-e-Castro, and Fonseca, forthcoming). Thus, lending to banks subsidized purchases of high-yield collateral assets.

Second, as discussed in Section 3, the BOE's FLS provided incentives for U.K. banks to lend to domestic firms, which skewed lending away from international clients. The combination of higher microprudential capital requirements and the FLS magnified the post-crisis contraction in cross-border lending (Forbes, Reinhardt, and Wieladek 2017).

Finally, banking support/narrow asset purchase programs may have also unintentionally encouraged zombie lending (Acharya et al. 2019). The SMP/OMT programs raised the value of the periphery-area bonds held by euro-area banks, thus raising the banks' capital (Brunnermeier and Sannikov 2012). But Acharya et al. (2019) argue that the OMT insufficiently recapitalized banks, which created incentives to avoid admitting losses and to "evergreen" loans. These loans to zombie firms adversely affected credit-worthy firms in zombie-filled sectors that were competing for specialized workers and customers (Hoshi 2006; Caballero, Hoshi, and Kashyap 2008). Acharya et al. (2019) argue that the ECB should have directly recapitalized banks instead.

### 4.10 Negative interest rates

A number of central banks have used NIRP: the ECB, the Riksbank, the SNB, the Danish National Bank (DNB), the central bank of Hungary, and the BOJ. These authorities calculated that negative deposit rates would lead financial institutions to lend more freely, lower other interest rates, and perhaps boost asset prices (lower panel of Figure 1). As discussed earlier, the stimulative effects of negative rates must contend with the pressure they put on lending margins, bank profits, and internal funding because commercial banks cannot charge their retail customers for deposits (Bernanke 2016; Jobst and Lin 2016; Bech and Malkhozov 2016; Heider, Saidi, and Schepens 2019; Shin 2016).[85]

***What did negative rates do to interest rates and asset prices?*** Negative deposit rate announcements broadly but modestly reduced money market rates and bond yields, and raised equity prices. That is, they usually have had similar effects on asset prices as conventional, positive rate cuts (Jobst and Lin 2016; Bech and Malkhozov 2016; Arteta et al. 2016; IMF 2017). There are two important exceptions, however: Negative rates have not substantially affected inflation expectations (Arteta et al. 2016) or retail deposit rates, which have sometimes been deliberately insulated (Bech and Malkhozov 2016; Heider, Saidi, and Schepens 2019).

Asset reactions to negative rates have not been wholly consistent with standard models,

[85] Brunnermeier and Koby (2018) modeled the negative side effects of negative or low rates on bank profitability. Rogoff (2017) argues that there are good ways to implement negative interest rates, i.e., making cash costly or impossible to hold, that would be superior to other forms of UMP or a higher inflation target.

however. They have been heterogeneous, often modest, and sometimes perverse, perhaps because most negative interest rate announcements have been anticipated. The BOJ's January 2016 negative rate announcement might be unusually informative because it was clearly unexpected; the BOJ had earlier ruled out negative interest rates. Indeed, this BOJ announcement produced strong financial reactions: The yield curve fell and flattened with long yields becoming negative, and corporations began to issue more long-term debt (Christensen and Spiegel 2019; IMF 2017). Surprisingly, expected inflation also fell (Christensen and Spiegel 2019).

The international spillovers of negative rates were consistent with those of other expansionary monetary policies (Arteta et al. 2016) with one interesting exception: During the period of the NIRP, the stock prices of firms in other Asian countries responded positively when Japanese financial stocks did poorly relative to the Nikkei 225. Fukuda (2017) conjectures that this occurs because investors saw Japanese financial firms investing abroad when negative rates adversely affected their domestic profit opportunities.

***Did negative rates prompt firms to lead/lag payments or collateral****?* Some potential problems with NIRP have not occurred: For example, counterparties have not strategically delayed collateral delivery to avoid receiving cash (Bech and Malkhozov 2016). The longer-run effects of negative interest rates might well differ from the immediate effects, however, as firms and individuals learn to adjust behavior to minimize their interest costs.

***How did banks adjust their portfolios?*** Any discussion of the effect of negative rates on banks must first acknowledge that such effects will be heterogeneous because banks themselves differ in their balance sheets and business models. For example, banks heavily engaged in maturity transformation will benefit from the steepening of the yield curve often associated with NIRP, if their funding costs decline (Heider, Saidi, and Schepens 2019).

Interest rate reductions stimulate activity by creating incentives for generic banks and agents to shift toward riskier assets, raising the prices of such assets and reducing riskless rates. Negative rates may lower banks' cash flow and net worth, however, and thereby make it more difficult to procure funding. This net effect leads to riskier lending, such as loans, mortgages, and financial assets, generally at lower rates (Basten and Mariathasan 2018; Heider, Saidi, and Schepens 2019; Bottero et al. 2019).[86] Such risk-taking is concentrated in poorly capitalized banks that lend to riskier borrowers, while safer borrowers tend to match with safer, low-deposit banks (Heider, Saidi, and Schepens 2019). Consistent with many banks' moves toward a riskier portfolio, NIRP also prompted banks to reduce their excess reserves and increase the maturity mismatch of their assets and liabilities (Basten and Mariathasan 2018; Bottero et al. 2019). This combination significantly increased the average risk weight on their assets.

***How do bank characteristics affect their reaction to negative rates?*** It has been commonly

[86] Bech and Malkhozov (2016) find perverse increases in Swiss mortgage rates but report that this does not occur in Denmark where mortgages are financed with pass-through bonds rather than deposits.

believed that because banks cannot pass on negative rates to retail depositors, negative rates could pressure the profits of banks that rely on such deposits (Bernanke 2016). Some studies do find that negative rates increase risk-taking and reduce lending by area banks that rely more on deposits (Heider, Saidi, and Schepens 2019) and these banks are perceived as being riskier (Nucera et al. 2017).[87] Banks also may see reduced interest income from floating interest rates. By reducing floating interest rates, NIRP can reduce cash flow to banks with floating rate mortgage assets, as well as small banks, which don't hedge interest risk and have less ability to diversify their business model (Molyneux et al. 2019). In addition to these factors, NIRP caused banks with more liquid balance sheets, that is, shorter maturity assets, to move into riskier assets, such as loans to smaller firms (Bottero et al. 2019). Doing business in competitive banking systems exacerbates all these factors as banks must pass lending-rate reductions through to borrowers but may not see their funding rates decline (Brunnermeier and Koby 2018; Molyneux et al. 2019). Larger banks have maintained their profitability through non-interest income, such as fees, and/or reductions in interest expenses (Basten and Mariathasan 2018; Nucera et al. 2017; Lopez, Rose, and Spiegel 2020).

***What effect do negative rates have on bank profitability?*** Researchers are not unanimous about the NIRP's ultimate effect on bank profits. Molyneux et al. (2019) calculate that bank profits fell in NIRP countries compared with those in other countries but most researchers find no strong evidence of significantly reduced bank profitability under NIRP (Jobst and Lin 2016; Basten and Mariathasan 2018; Lopez, Rose, and Spiegel 2020; Arteta et al. 2016, 2018).

The very modest evidence for reduced profitability is unsurprising for several reasons, however. First, negative rates may improve economic conditions sufficiently to offset a lagged effect on profits (Altavilla, Boucinha, and Peydró 2018). Second, banks benefitted from capital gains from the asset price increases associated with the NIRP announcements (Lopez, Rose, and Spiegel 2020). Third, central banks set rates endogenously and will avoid rates below the "reversal rate" of Brunnermeier and Koby (2018), below which policy is contractionary. Consistent with this, Jobst and Lin (2016) argue that further cuts would have diminishing returns.

# 5 Macroeconomic effects of unconventional policies

Studying UMP effects 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. We start by discussing the methods used in the literature to infer macroeconomic effects of UMP.

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[87] Bottero et al. (2019) and Lopez, Rose, and Spiegel (2020) dispute the idea that high-deposit banks are unusually vulnerable to negative rates.

### 5.1 **Methods to study macroeconomic effects of unconventional monetary policy**

The literature on the macroeconomic 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. PB, but are more dependent on the assumed structure of the economy. In contrast, VARs may be less prone to misspecification because they are more agnostic about the economic structure and the mechanism, while still summarizing the dynamic effects of policy shocks.[88]

***Calibrated DSGE Models***: DSGE models that feature a role for UMP can assess the macroeconomic implications of the financial market effects of UMPs. Specifically, a DSGE model can be simulated to estimate the effect of UMP on variables of interest, such as output, when constrained by the ELB. The policy intervention can be sized to resemble a particular asset purchase episode, e.g., the Fed's QE2, and its financial market effects calibrated to asset-price effects from event-studies. The difference in simulated model outcomes with and without the policy then measures the model-implied macroeconomic effects of the intervention. Researchers have used this strategy to assess the macroeconomic effects of the PB, limits-to-arbitrage due to leverage constraints, and signaling channels of asset purchases.

***Identified VARs:*** The second method of assessing the macroeconomic effects of UMP is the identified VAR. The need to identify and measure UMP shocks is the biggest hurdle to using VARs to assess UMP. Although the federal funds rate, perhaps augmented with "path" shocks, is widely used to gauge conventional monetary policy, there is no consensus on the analogous UMP instrument. Researchers have used central bank assets, interest rate spreads, and shadow interest rates to measure the impact of asset purchases and the path factor to measure FG.

Conditional on the measure of unconventional policy, however, VAR studies identify monetary shocks with restrictions that are similar to those used in the conventional monetary policy literature. These restrictions can be contemporaneous restrictions that the policy shock affects the macroeconomy with a delay, sign restrictions that require an expansionary policy shock to raise output and prices, or identification obtained through external instruments, such as high-frequency changes in the yield curve around FOMC announcements. The pre-crisis literature has widely used and critically assessed such identification restrictions.

### 5.2 **What are the empirical macroeconomic effects of unconventional monetary policy?**

We now discuss estimates of the macroeconomic effects of UMP. We start with selected papers that estimate either the impact of UMP for multiple programs or are well-suited to illustrate general empirical approaches to identification and specification.

[88] We do not detail simulation results from the Federal Reserve Board's FRB/US macro-econometric model, used by Bernanke, Kiley, and Roberts (2019) to explore the impact of policy rules at the ZLB and with which Bernanke (2020) finds that QE and FG together add stimulus equivalent to 3 percentage points of conventional cuts.

The use of cross-sectional data allowed researchers to obtain more econometric power from the particularly short UMP sample early in the crisis. Gambacorta, Hofmann, and Peersman (2014) estimate a panel VAR using data from eight monetary areas over the sample from 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 UMP instrument at the ELB, temporarily increases output and prices. Six months after a 3 percent increase in the central banks' assets, output and prices reach peak effects of around 0.04-0.10 percent and 0.01-0.04 percent respectively.[89]

One difficulty with using assets purchased as a QE instrument is that expectations (announcements) almost certainly change asset prices and therefore such price changes and macroeconomic effects might precede the purchase of the securities. Therefore, Weale and Wieladek (2016) assume that the QE policy instrument is the cumulated level of announced purchases by the Fed and BOE for March 2009-May 2014. Although this approach has difficulty assessing the effects of open-ended programs because purchases are contingent on economic developments, these authors find QE has expansionary effects. Averaging across four different identification methods, an asset purchase of 1 percent of GDP by the Fed has peak effects on U.S. real GDP of 0.58 percent and CPI of 0.62 percent. Moreover, a BOE asset purchase of 1 percent of GDP has somewhat smaller, but still substantial, peak effects on U.K. real GDP of 0.25 percent and CPI of 0.32 percent. The authors find that asset purchases decrease long-term yields in the U.S. but not in the U.K.

It is difficult to compare the macro effects of heterogeneous UMP or of policies between conventional and unconventional periods. That is, how big of an asset purchase is comparable to a 25 b.p. negative interest rate? The use of shadow interest rates implied by TSMs as the UMP instrument permits researchers to conveniently summarize the stances of heterogeneous UMP as well as compare the effects of equivalent shocks in conventional and unconventional periods.[90] Wu and Xia (2016) use their U.S. shadow rate in a factor-augmented VAR to show that macroeconomic effects of an unanticipated change in the policy instrument, identified through timing restrictions, are similar to the pre-ELB period, where the federal funds rate is the policy instrument. A counterfactual exercise for the ELB period (2009-2013) shows that Fed UMP had non-trivial effects, reducing the unemployment rate by 1 percent at peak.

Finally, Eberly, Stock, and Wright (2019) use another approach to identifying UMP shocks and assessing their effects. The authors combine a monthly SVAR identified via external instruments with a Phillips curve to evaluate how monetary policy influenced the recovery from the financial crisis. They identify two monetary shocks: federal funds shocks, which are associated with conventional policies, and slope shocks, which are the joint effect of QE announcements and FG on the slope of the term structure. The instruments for both shocks are constructed from high-frequency changes in interest rates around FOMC announcements. Slope

[89] The VAR cannot estimate effects on long-term yields as it only uses central bank assets, output, prices, and VIX.
[90] Wu and Xia (2016) show that the shadow rate is highly correlated with Fed assets, until QE3.

policies have a modest, but still positive macro impact: A one percentage point expansionary slope shock decreases the unemployment rate at peak by about 0.7 percentage points. Nevertheless, the ZLB was a significant constraint as slope policies provided stimulus equivalent to only a -1 percent federal funds rate when the Fed would have wanted to put the policy rate at -5 percent.

We now discuss estimated domestic and international effects of specific UMP programs.

***What are the macroeconomic effects of US and UK QE1?*** Several papers studied the effects of Fed and BOE QE1 using VAR methods and an interest rate spread—typically a mortgage spread or a long-term Treasury spread—as a policy metric. Starting with an event-study estimate of the effects of QE on rate spreads, they indirectly assess the macroeconomic effects of QE by calculating the impact of a spread shock using standard VAR identification restrictions. Theoretical models, such as Gertler and Karadi (2011, 2013) and Cúrdia and Woodford (2011), rely on mechanisms that allow QE to reduce term or credit spreads, providing a motivation for this empirical literature to focus on the transmission of QE through spreads. Moreover, by influencing mortgage spreads, UMP can affect residential investment, consumption-savings decisions, and the disposable income of household with mortgages.

Using a SVAR identified with contemporaneous restrictions, Walentin (2014) establishes that exogenous shocks to U.S. mortgage spreads had substantial effects on GDP throughout the 1983-2011 sample but had particularly strong effects in the last few years of the sample. The stronger effects at the end of the sample suggest a need to allow for time variation in estimated parameters. To investigate the effects of the Fed's QE1, Walentin (2014) combines VAR estimates with Hancock and Passmore's (2011) estimates of QE1 on mortgage effects. The result implies that QE1 raised GDP at peak by 3.8 percent and house prices by 5.1 percent.

Other papers focused on QE effects through term spreads. Using a time-varying-parameter SVAR identified with sign restrictions, Baumeister and Benati (2013) find that reduced term spreads produce large GDP and price effects and that the Fed and BOE QE1 programs averted disastrous drops in output and prices in the respective economies. To size the Fed and BOE QE1 shocks, Baumeister and Benati (2013) use Gagnon et al.'s (2011) and Deputy Governor Bean's (2009) estimates of 60 b.p. and 50 b.p. declines in the U.S. and U.K.'s respective term spreads. The VAR implies that the Fed's QE1 stopped inflation from reaching a low of -1 percent and output growth from reaching a trough of -10 percent. Similarly, the BOE's QE1 prevented a fall in inflation to -4 percent and a trough in output growth of -12 percent.

Kapetanios et al. (2012) also use several variants of time-varying VARs to assess the macro effects of the BOE's QE1. Using estimates from Joyce, Tong and Woods (2011) of the fall in term-spreads due to BOE QE1, Kapetanios et al. (2012) infer that the peak effects of the program were 1.5 percent on real GDP and 1.25 percent on CPI inflation. These effects are substantial but not nearly as large as those found by Baumeister and Benati (2013).

These studies that use mortgage and term spreads to infer the effects of the early Fed and BOE QE find large macro effects. This is not surprising because these studies use the large, event-study estimates of QE effects on interest rate spreads to quantify the policy instrument, while inferring the effects of reduced interest rate spreads using a VAR. Because mortgage and term spreads are strongly countercyclical, the models imply large stimulative effects of QE shocks.

***What are the macroeconomic effects of the Fed's QE2?*** Several papers study the macroeconomic effects of the Fed's QE2 with calibrated DSGE models. We detail the theory behind these DSGE models in Subsection 2.2. Chen, Cúrdia, and Ferrero (2012) and Gertler and Karadi (2013) assess the Fed's QE2 effects with calibrated DSGE models that respectively include PB effects from financial market segmentation or binding leverage constraints that limit arbitrage by financial intermediaries. Both models consider a $600 billion purchase of long-term government bonds (matched to the Fed's QE2), together with a credible commitment to hold short rates at zero for four quarters. Both papers find this stimulus has modest output effects. In the Chen, Cúrdia, and Ferrero (2012) model, GDP rises only 0.13 percent while Gertler and Karadi (2013) find a larger (peak) increase in output of around 1 percent.

The effects on GDP depend first on the calibration that determines the extent of financial frictions in the model. For instance, the very small effects on output in Chen, Cúrdia, and Ferrero (2012) is partly due to the small degree of market segmentation that the authors estimate using pre-crisis data.[91] Second, Chen, Cúrdia, and Ferrero (2012) and Gertler and Karadi (2013) both find that a credible central bank commitment to hold short-term interest rates at zero generates most of the GDP effects (at least 70-80 percent). That is, the signaling channel can be powerful even in DSGE models that also account for PB and limits to arbitrage effects.[92]

Long-term bond purchases by the central bank allow for this signaling effect endogenously in the Bhattarai, Eggertsson, and Gafarov (2019) DSGE model. The authors calibrate their model to match KVJ's event-study estimates of the signaling effects of the Fed's QE2 on long-term yields and expected inflation as well as the output and inflation drop during the Great Recession. They find that the Fed's QE2 increases output by 1.6 percent and inflation by 1.4 percent on impact.

***What are the macroeconomic effects of the ECB LTRO?*** Two papers have used different methods to laud the impact of liquidity provision through LTROs. Cahn, Matheron, and Sahuc (2017) extend the Gertler and Kiyotaki (2010) set-up to study the ECB's LTRO policies. The theoretical frameworks discussed in Subsection 2.2 have thus also been used to estimate

[91] Gertler and Karadi (2013) calibrate effects on the long-term yield while Chen, Cúrdia, and Ferrero (2012) do not, which can affect the quantitative predictions.

[92] Sims and Wu (2019a) extend Gertler and Karadi (2013) to show that endogenous QE, combined with a commitment to an extended zero policy rate, can have quantitatively large effects. For instance, in a Great Recession simulation, QE that expands the central bank's balance sheet by 25 percent of GDP, coupled with zero policy rates for 2 years, largely negates the effect of a binding ZLB. In a similar vein, Debortoli, Gali, and Gambetti (2019) and Garin, Lester, and Sims (2019) also argue that the ZLB has not affected the transmission of shocks in the U.S. while Wu and Zhang (2019b) find that U.S. has followed a historical Taylor rule using UMP tools at the ZLB. As we mentioned before, however, Eberly, Stock, and Wright (2019) reach a different conclusion.

macroeconomic effects of UMP that are not asset purchases. Boeckx, Dossche, and Peersman (2017) in contrast, use a SVAR to study the effect of an exogenous increase in ECB LTRO assets on financial and macro variables.

Cahn, Matheron, and Sahuc (2017) determine that ECB LTRO liquidity injections reduced credit spreads. They find that the 6- and 12-month LTROs reduced credit spreads by 400 b.p. and raised output and the GDP deflator by 2.5 percent and 0.5 percent respectively. Boeckx, Dossche, and Peersman (2017) also find that an exogenous increase in ECB LTRO assets raises bank lending, reduces interest rate spreads and temporarily raises output and prices. A counterfactual exercise implies that the 3-year LTRO boosted output and inflation by 1 percent in 2012.

Empirical studies of liquidity impact have problems with credibly sorting out changes from supply versus demand. Darracq-Paries and De Santis (2015) estimate the macroeconomic effects of the ECB's LTRO program using responses to the euro-area Bank Lending Survey (BLS) to separately identify supply and demand shocks and to calibrate the size of the credit supply shock. The methods imply that the 3-year LTRO shock modestly raised the level of euro-area real GDP, inflation and bank loans to non-financial corporations.

***What are the macroeconomic effects of BOJ reserve expansion?*** The similarities and differences in central bank conduct of UMP can shed light on whether and how UMP works. In contrast to the later Fed or BOE focus on the asset side of the balance sheet, the BOJ explained its early (2001-2006) QE in terms of reserve expansion, which led researchers to use reserves as the relevant policy instrument in their empirical framework.[93]

Schenkelberg and Watzka (2013) estimate the impact of BOJ's early QE programs (1995-2010) using a VAR with sign restrictions motivated by the implications of DSGE models at the ZLB, such as those of Eggertsson and Woodford (2003) and Jung, Teranishi, and Watanabe (2005) that we discussed in Subsection 2.3. The authors use bank reserves at the BOJ as the UMP instrument. A QE shock that increases reserves by 7 percent raises output by 0.4 percent at peak, while significantly decreasing 10-year JGB rates, with an impact effect of 7 b.p.. The effects on consumer prices, however, are very small and the effects on both output and prices are short-lived.

The ZLB creates a potentially important nonlinearity in the behavior of short-term rates and it is more realistic to consider a model where the switch between conventional policy and UMP is endogenous. To account for both these issues, Hayashi and Koeda (2019) estimate the impact of the BOJ's QE programs using an endogenous regime-switching VAR in which the central bank uses a standard (positive) interest rate reaction function in the first regime, but reacts by manipulating the supply of excess reserves (i.e., QE) at the ELB in the second regime. A QE

[93] In Section 2, we termed such reserve expansion policies as "pure" QE policy while using the change in the composition of central bank assets as our definition of QE.

shock of 10 percent of GDP leads to a peak effect of 1.4 percent on the output gap and a peak effect of about 0.55 percent on inflation. The output gap effects are persistent, unlike Schenkelberg and Watzka (2013), but those on inflation are transitory, as in Schenkelberg and Watzka (2013).

Both Schenkelberg and Watzka (2013) and Hayashi and Koeda (2019) thus find that the BOJ's QE policies had stronger effects on output than inflation. This accords with the significant difficulty that Japan has faced in raising inflation.[94]

***How did Fed UMP spill over internationally?*** Event studies that found substantial international asset price spillovers of Fed QE motivated a VAR literature to investigate dynamic spillover effects, both financial and real, on both emerging markets (EMEs) and advanced economies. An important question is whether UMP by major central banks produced positive or negative spillovers over time. In particular, did the expansionary interest rate and stock price effects outweigh the appreciation of the recipient's exchange rate?

Bhattarai, Chatterjee, and Park (2018) estimate spillover effects of U.S. QE on EMEs using a VAR with contemporaneous restrictions, using assets purchased outright as the UMP instrument. A 20 percent increase in Fed purchases ($400 billion) appreciates emerging market (EM) exchange rates by 2.5 percent, EM stock prices by 10 percent, and reduces EM long-term yields by 30 b.p..[95] Moreover, capital inflows to EMs increase by around 2 percent. Despite such large asset price changes, however, the macroeconomic spillovers were insignificant, perhaps because the exchange rate effects negated the expansionary effects on other asset prices and capital flows.

As we mentioned before, to ascertain the domestic effects of QE, several papers use a long-term interest rate spread, instead of a balance sheet variable, as a policy measure. Chen et al. (2016) do so in a vector error correction model to estimate the international spillovers of Fed QE. In advanced economies, QE1 did not increase capital inflows but boosted growth and inflation.

A common theme is that the Fed's QE spilled over significantly but heterogeneously across EMEs. Thus, the Fed's QE1 fostered capital inflows in some EMEs (Chen et al. 2016; Bhattarai, Chatterjee, and Park 2018). Overall, there were heterogeneous effects on EMEs, with particularly strong effects on the "Fragile Five," i.e., Brazil, India, Indonesia, South Africa, and Turkey, which are related to their trade and fiscal fundamentals (Bhattarai, Chatterjee, and Park 2018).

***What are the macroeconomic effects of Fed FG?*** A growing literature has also estimated the macroeconomic effects of FG, with a focus on that of the Fed. One challenge is that FG can be either Odyssean or Delphic, and—assuming the guidance occurs during a downturn or crisis—the two variants may be expected to have opposite macroeconomic effects: Odyssean FG should

[94] Ito and Mishkin (2006) briefly review the literature's conclusions on the importance of managing expectations in the context of the Japanese experience from 1999-2006: Deflation is costly and is difficult to end. While these authors criticize the BOJ for managing market expectations poorly, such as prematurely terminating the ZIRP in 2000, they also judge that BOJ expectations management improved later in the sample.

[95] Fed asset purchases also reduce long-term, domestic yields.

be stimulative as it reduces expected future interest rates, while Delphic FG might be contractionary if it conveys negative news.

Campbell et al. (2012) apply the Gürkaynak, Sack, and Swanson (2005) methodology that decomposes yield curve changes around FOMC releases into "target" and "path" factors. The target factor reflects the level of short rates; the path factor, which describes expected future rates one year out, reflects FG. In a pre-crisis sample, Campbell et al. (2012) find that FG tends to be Delphic: Path shocks decrease Blue Chip unemployment forecasts.[96] FG effects are not statistically significant for the crisis period, however, although the sample is much shorter.

Like Campbell et al. (2012), Bundick and Smith (forthcoming) extract a path factor as a measure of FG, and then put it in a VAR to infer the macro effects. These latter authors find post-crisis evidence of an Odyssean channel, as their FG shock initially decreases the 2-year Treasury yield while modestly boosting output and prices: A FG shock that reduces the two-year ahead future rate by 6 b.p. has a peak effect on output of 0.15 percent and prices of 0.05 percent.

# 6 Evaluations of unconventional monetary policy

This section reviews the disparate evaluations of the efficacy of UMP from economists and central bankers.

## 6.1 **Skepticism on the effects of broad asset purchases and forward guidance**

Subsection 4.5 showed that the great majority of research found that central banks' broad asset purchases and FG achieved the immediate goals of reducing medium- and long-term yields, including private borrowing costs such as corporate yields and mortgages (Gagnon 2016). Yet some prominent economists are skeptical that the purchases had much effect, that the effects persisted, or that later rounds of purchases continued to work: Nobel laureate Eugene Fama said, "They're basically neutral events. I don't think they do very much." (Fama 2013).

***Did the broad asset purchases have sizeable effects on yields?*** The first critique argues that conventional estimates of the Fed's asset purchases significantly overstate the true impact in two ways: 1) by omitting events with no purchase news, in which yields tended to rise, and 2) by attributing "signaling" effects to asset purchases (Greenlaw et al. 2018).[97]

Greenlaw et al. (2018) note that nominal and real yields did not decline, on balance, during the asset purchase programs: i.e., in the period shown by the shaded bars in the top panel of Figure 5. The authors term these patterns "an optical challenge for fans of QE." They go on to show that

[96] Nakamura and Steinsson (2018) find a similar negative output effect of unidimensional monetary shocks.
[97] Foerster and Cao (2013) take the opposite view from Greenlaw et al. (2018) on bias in event-study estimates. Citing surveys, news, and internet searches, they argue that standard event studies underestimate the effect of LSAPs purchases by ignoring market expectations of such announcements. Greenlaw et al. (2018) give some credence to this view when they assess that markets expected a substantial portion (but "considerably less than 50 percent") of the QE1 announcements, meaning that some QE1 effects were priced-in prior to the announcements.

yields tended to rise on days of FOMC announcements and/or speeches by the Chair or days in which monetary news seemed to dominate headlines (bottom panel, Figure 5).

[Figure 5 here]

This argument implausibly assumes, however, that market expectations of UMP respond only to Fed announcements or monetary news. After the initial Fed and BOE asset purchases in 2008-2009, all sorts of news doubtless changed market expectations. There is no reason to expect yields to decline during a purchase program or on Fed announcement days. In fact, to the extent that UMP works and economic conditions improve during the program, one would expect yields to increase over the course of a program. Thus, summing yield changes on Fed announcement days or days of monetary news does not plausibly estimate the impact of a program after 2009.

Greenlaw et al. (2018) also focus explicitly on days of Fed announcements and important monetary news (Reuters' Days) during the QE1 program, calculating that nominal (real) 10-year Treasury yields fell 17 to 48 (40 to 91) b.p., depending on the event set, which is lower than the usual ranges from QE1 event studies.

Greenlaw et al. (2018), however, omitted two important expansionary announcements from their calculations—November 25 and December 4, 2008: Including them raised the estimated QE1 effects on 10-year Treasuries from 17 to 49 b.p., using the "Fed Days" event set (Gagnon 2018; Bernanke 2020). Thus, QE1 policies still had fairly large effects once the proper event set was used.

We agree with Greenlaw et al. (2018) that signaling probably produced a substantial part of "QE1" announcement effects, although we would add that balance sheet policies might have been useful or even necessary to convey the signals, as we discuss in Subsection 2.2. But we also think most economists who study UMP realize the estimated effects were likely due to some combination of FG and balance sheet policies (Kuttner 2018). The relative importance of these policies is uncertain and depends on perceptions of policy and the economy (see Subsection 4.6).

***Did the purchase effects on yields persist?*** Some analysts make a subtly different critique: While they concede large effects from surprising asset purchase announcements, they counter that yields generally rose somewhat in the months that followed such expansionary announcements (Greenlaw et al. 2018), which they interpret as indicating that the announcement effects were transient or quickly "wore off."

It is unusual to assume these shocks quickly "wear off." Asset prices should be discounted, risk-adjusted estimates of future payoffs; rational asset pricing limits predictability in returns. Speculators arbitrage away strong predictable patterns. Many studies have claimed to predict asset returns, only to be overturned by more careful or out-of-sample evidence (e.g., Faust, Rogers, and Wright 2003; Welch and Goyal 2008). When predictability is established, it tends to be limited in practice. For example, studies of stock return predictability estimate $R^2$s for monthly returns of 0.002 to 0.01 (Campbell and Thompson 2008). It would be surprising if repeated central bank bond purchases over a period of years had transient effects on yields. It is more likely that nonmonetary shocks raised expected growth and yields.

Researchers contest the empirical evidence on the persistence of UMP shocks. The SVAR in Wright (2012) implies that UMP shocks are relatively transient. Swanson (2019) develops an econometric model that implies FG shocks have a half-life of 6.5 months, but that estimate is not statistically significantly different from complete persistence.[98] Swanson (2019) cites Duffie (2010) who argues for limited dynamics in some asset prices.[99] None of the cited examples seem to justify many-months-long price dynamics in thickly traded, closely watched bond markets, however. There is also contrary econometric evidence. Neely (2016) shows the SVAR in Wright (2012) fails tests of structural stability and forecasts poorly, indicating misspecification. The SVAR also implies too much in-sample return predictability to be consistent with rational asset pricing and reasonable risk aversion. Altavilla et al. (2019) use methods like those of Swanson (2019) and find persistent QE effects. Kuttner (2018) declares the issue to be unsettled.

Further evidence against transient shocks is that respondents to the Survey of Professional Forecasters expected persistent UMP effects on yields (Altavilla and Giannone 2015). Finally, micro evidence shows that UMP shocks persistently changed lending quantities/types, portfolio choices and capital flows and such reactions didn't decline over time (see Subsection 4.7). Transient or weak shocks would not repeatedly change such quantities.

So, how to explain the rise of yields in the months after expansionary shocks? It is possible markets consistently, irrationally overreacted. Hamilton (2018) cites the large stock market reaction to President Trump's election that reversed within a few hours. But this was a one-off. It is difficult to credit systematic overreactions to UMP because there would have been many predictable, unexploited profit opportunities over 5 to 10 years. A more likely explanation is that UMP announcements systematically improved confidence, increased investment, and raised yields, offsetting the original declines. A third explanation for endogenously increasing yields is that the U.S. Treasury extended the maturity of U.S. debt. Greenwood et al. (2014) argue that this action raised 10-year Treasury yields by about 45 b.p. or about 1/3 of the cumulative impact of the Fed's QE policies, as estimated by other studies.

***Did the effects of later purchases decline?*** Early Fed and BOE asset purchase announcements produced far larger contemporaneous effects on bond yields than did later announcements from any central bank. Figure 6 shows a decline in the size of 10-year Treasury yield changes after the initial Fed QE1 announcements in 2008-2009. Some researchers see this as evidence that later purchase programs were less effective (Martin and Milas 2012), perhaps because liquidity conditions normalized after the crisis or because markets learned they were ineffective. Others argue that markets learned to anticipate and price UMP into yields by the time of the later QE

[98] Swanson (2019) finds asset purchase shocks are completely persistent when he excludes March 18, 2009.
[99] Duffie (2010) makes a careful argument for limited asset price dynamics, based on frictions that limit arbitrage. The patterns typically result from sporadic trading in relatively thin markets (e.g., for a stock) and last only a few days but much longer effects are possible. It is unclear how such examples could explain transient UMP effects.

programs, producing smaller contemporaneous impacts (Foerster and Cao 2013). That is, in later rounds, all economic news influenced expectations of UMP and bond pricing. Consistent with this hypothesis, De Santis (2020) identifies expectations of ECB QE from Bloomberg references and constructs announcement surprises, inferring that the ECB APP reduced yields by about 70 b.p. This figure is larger in absolute value than those of studies that did not account for expectations and proportionally comparable to estimates for early Fed and BOE asset purchases.

[Figure 6 here]

Cahill et al. (2013) and Joyce, McLaren, and Young (2012) support this latter interpretation. They show that local-supply effects of asset purchases were consistent over time if one controls for the size of monetary surprises. That is, surprises in maturity patterns of central bank purchases continued to affect relative returns/yields across maturities in the same way over time.

The "taper tantrum" of June 19, 2013 showed that markets continued to respect the importance of asset purchases well into 2013. In a June 19, 2013, press conference, then-Fed Chairman Ben Bernanke suggested the Fed might reduce its bond purchases later in 2013. Figure 7 shows how this surprising suggestion roiled financial markets, substantially increasing long-term U.S. bond yields and the foreign exchange value of the dollar.[100]

[Figure 7 here]

### 6.2 Central bank evaluations of unconventional monetary policy

Central banks were generally positive, but measured, about the impact of the many types of UMP. Tellingly, they repeatedly used similar types of programs and borrowed ideas from each other—e.g., asset purchases, incentives for lending, negative interest rates— suggesting they considered foreign programs to be successful.

The most important and closely watched programs were the broad asset purchase programs. Fed officials—Bernanke (2012), Powell (2013), and Fischer (2014)—offered measured appreciation, stating that such transactions reduced yields and significantly aided the recovery. Fed Vice Chair Stanley Fischer said, "I consider quantitative easing to have been largely successful" (Fischer 2014). 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…and reversing the deflationary pressures" (Draghi 2015b). The BOJ opines 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" (Bank of Japan 2018). Former Fed Chair Bernanke summarized his view of research on QE and FG: "[T]he new tools have proven quite effective, providing substantial additional scope for monetary policy despite the lower bound on short-term interest rates" (Bernanke 2020).

[100] Greenlaw et al. (2018) cite surveys of Fed policy to argue that the announcement caused this turmoil through expectations of short rates, i.e., signaling, rather than of strict balance sheet policy, i.e., portfolio balance.

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....[I]t has led to a convergence in the cost of borrowing across euro-area countries" (Draghi 2015a). Mark Carney likewise expressed 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).

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. Deputy Governor Ben Broadbent of the BOE recognized the limitations of such policies. "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). Then-Fed-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 has remained persistently low since the mid-1990s. Hiroshi Nakaso, Deputy Governor of the BOJ, characterized the results of 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).

## 7 Discussion and conclusion

The severe, global Financial Crisis of 2007-2009 initially prompted central bankers to respond with massive injections of liquidity and dramatic reductions in short-term interest rates. The ELB's constraint on conventional monetary policy then challenged central banks to find new tools with which to stabilize financial markets and stimulate their economies. Central banks responded with a variety of methods: FG, broad and narrow asset purchases, bank lending support, and negative rates on bank reserves. The BOJ's 1999-2006 experiences presaged the use of many of these tools.

Central banks tailored their UMPs to the structure of their economies and to their specific problems. For example, the Fed and BOE used mostly broad asset purchases to stimulate their economies—in which bond markets are so important. The ECB and BOJ, whose economies were peripheral to the origins of the financial crisis and more dependent on banking, initially focused more on providing funding to their banks but later added large, broad asset purchase programs.

Recognizing UMP's importance, a large literature has modeled its potential effects and evaluated its impact on financial markets and the macroeconomy. Despite the importance of such knowledge, most economists do not understand the research on it. This paper has analyzed and synthesized theoretical and empirical studies of UMP to disseminate this knowledge.

Economists developed theoretical models based on several mechanisms—market segmentation, leverage constraints, and signaling effects under time-consistent policy—that rationalize how the various forms of UMP can influence the economy. Asset purchases, i.e., QE, are perhaps the most important form of UMP. Our discussion of the theory of QE defines it as a change in the composition of government debt or the central bank's assets, holding fixed the level of government debt or the central bank's net asset position. We first show that QE is ordinarily neutral in DSGE models, even when Ricardian equivalence does not hold, given appropriate formulations of conventional interest rate and debt policy.

To introduce a role for QE, standard DSGE models must be extended with appropriate financial frictions, such as market segmentation and leverage constraints that limit arbitrage. To model the signaling channel of QE, one must consider optimal policy without commitment. Other UMPs, such as FG and NIRP, can also be rationalized in DSGE models. In particular, theories of optimal monetary policy under commitment create a role for FG at the ZLB. Modifying standard money demand formulations or taxing banks similarly rationalizes NIRP. Moreover, our theoretical analysis explains that if credible FG is possible, then there is no reason to engage in QE for signaling purposes.

Empirical event studies, low-frequency studies, quantity-of-debt studies, and micro studies provide strong evidence that large central bank asset purchases moved all sorts of asset prices in the desired direction, spilled effects over internationally, and prompted portfolio reallocation. The Fed's QE also spilled over to emerging markets through asset price changes and capital flows. The effects are heterogeneous over time and across countries. Narrow asset purchase programs and bank lending support programs have normalized market functioning and encouraged intermediation.

Although the vast majority of research on UMP programs indicates that they were useful tools, researchers still debate the size and persistence of asset-price effects from bond purchases and/or FG. Fiscal deficits and debt management may have worked against the overall effect of UMP and may partially explain some findings of relatively transient impact on yields.

Researchers study the macro effects of UMP with DSGEs and structural VARs. The quantitative DSGEs are built around theoretical mechanisms to give UMP some role. SVAR researchers use contemporary impact and sign restrictions, as well as external instruments, to identify UMP policy shocks. In the DSGE and SVAR literatures, researchers often size policy shocks with event-study estimates of purchase effects on long-term yields. These models find that QE raised output and inflation through reduced interest rate spreads or long-term interest rates. Although views differ on the topic, many researchers believe that while UMP improved macro outcomes, it did not fully offset the ELB constraints on monetary policy.

Although UMP stabilized financial markets and stimulated the macroeconomy, such policies potentially have costs. For example, LSAPs might put the central bank at odds with the Treasury in determining the maturity structure of the national debt. Similarly, negative rates on bank deposits with the central bank can put pressure on bank profitability and the health of the financial system, potentially producing contractionary effects. The BOE FLS seems to have reduced international financial intermediation by skewing incentives toward domestic lending. In addition, particular central banks have specific difficulties with UMP policies. For example, the need to apportion bond purchases among fragmented, national bond markets makes such purchases more complex for the ECB than for the Fed, BOE, or BOJ.

UMP has produced unsatisfactory results for some countries by some important metrics. Most notably, the BOJ's strong expansionary measures since 2013 have not persistently boosted inflation or dislodged now long-held expectations of zero inflation.

Despite the costs and shortcomings, policy makers generally gauge UMP programs as qualified successes in substantially improving financial conditions, reducing the magnitude of the recession, and/or raising growth and avoiding downside risks to price stability. Yellen (2012) summarized this sentiment well: "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."

Despite the basically positive assessment of UMP tools, central banks still see short-term interest rate management as the default policy. As recently as mid-2019, the Fed, ECB, and BOE were moving toward normalizing policy with reduced or reversed asset purchases and higher short rates for the Fed and BOE. The ECB returned to asset purchases in November 2019, however, while the coronavirus crisis of 2020 prompted all four central banks to introduce or increase asset purchase programs and/or bank lending support and led the Fed and BOE to reduce conventional policy rates toward zero. Although UMP now appears to be a permanent part of the central bank toolkit, our assessment of the costs and benefits suggests that central banks are correct in making short-term interest rate management the default while retaining UMP for contingencies of unusual market stress and/or constrained short rates.

Indeed, for some years analysts have recognized that a relatively low-growth, low-inflation environment will produce low neutral interest rates that limit the use of conventional policy tools and oblige the retention of UMP. The adequacy of those UMP tools is debated, however. Reifschneider (2016) assesses that a combination of conventional tools, asset purchases, and FG will be adequate to compensate for most negative shocks, and Bernanke (2020) argues that, in retrospect, that the new tools provided "substantial additional scope for monetary policy despite the lower bound." In contrast, Eberly, Stock, and Wright (2019) take the position that the ZLB imposed real costs on the U.S. economy. That is, Fed UMP produced only a modest fraction of the desired stimulus in the recovery from the great financial crisis.

This article commenced with a quote from Chairman Ben Bernanke that highlighted the lack of convincing theoretical explanations for the measurable impact of UMP. Our study of this literature bears out a large measure of truth in this remark. While theoretical general equilibrium models rationalize the impact of broad asset purchases on yields and economic activity, they predict only a small subset of empirical findings. In addition, the approach of existing empirical work makes it difficult to rule out alternative transmission mechanisms, such as market segmentation and participation constraints (Vayanos and Vila 2009; Chen, Curdia, and Ferrero 2012) or binding leverage constraints (Gertler and Kiyotaki 2010; Gertler and Karadi 2011), or the signaling effects of asset purchases (Bhattarai, Eggertsson, and Gafarov 2015).

Empirical work does support certain theoretical mechanisms, however. For example, micro studies find heterogeneous rebalancing of portfolios in the wake of asset purchases, which is consistent with market segmentation (Carpenter et al. 2015; Joyce, Liu, and Tonks 2017). Cross-country evidence indirectly supports the signaling effects of asset purchases in that the relatively unsuccessful BOJ asset purchases from 2001-06 were associated with a reduced average maturity of the BOJ's portfolio (McCuley and Ueda 2009), while more successful programs such as those by the Fed had the opposite effect on the maturity of central bank portfolios. Similarly, the event-studies and SVAR evidence supporting higher expected inflation following US QE1 and QE2 are consistent with the predictions of macroeconomic models. In summary, theory and empirical work on UMP are not tightly linked, but evidence supports some specific mechanisms, which does not necessarily cast doubt on other transmission mechanisms.

Finally, we identify some opportunities for fruitful research. While theoretical research has modeled various UMP channels and showed that the ELB constraints matter, it could better connect with empirics. That is, researchers might develop general equilibrium models that incorporate more 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 observed local supply and duration effects. Moreover, future work could focus more on welfare implications of UMP.

Empirical work could also be better motivated by theoretical predictions. 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 effects of UMP, where the state might be the shape of the yield curve or the degree of stress in financial markets.

# 8 References

Acharya, Viral V., Tim Eisert, Christian Eufinger, and Christian Hirsch. 2019. "Whatever It Takes: The Real Effects of Unconventional Monetary Policy." *Review of Financial Studies* 32 (9): 3366-411.

Aguiar, Mark, and Manuel Amador. 2014. "Chapter 11 - Sovereign Debt." In *Handbook of International Economics*, edited by Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, 4: 647–87. Amsterdam: Elsevier.

Alpanda, Sami, and Serdar Kabaca. 2020. "International Spillovers of Large-Scale Asset Purchases." *Journal of the European Economic Association* 18 (1): 342–91.

Altavilla, Carlo, Miguel Boucinha, and José-Luis Peydró. 2018. "Monetary Policy and Bank Profitability in a Low Interest Rate Environment." *Economic Policy* 33 (96): 531–86.

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa. 2019. "Measuring Euro Area Monetary Policy." *Journal of Monetary Economics* 108: 162–79.

Altavilla, Carlo, Fabio Canova, and Matteo Ciccarelli. 2020. "Mending the Broken Link: Heterogeneous Bank Lending Rates and Monetary Policy Pass-Through." *Journal of Monetary Economics* 110: 81–98.

Altavilla, Carlo, Giacomo Carboni, and Roberto Motto. 2015. "Asset Purchase Programmes and Financial Markets: Lessons from the Euro Area." European Central Bank Working Paper 1864.

Altavilla, Carlo, and Domenico Giannone. 2015. "The Effectiveness of Nonstandard Monetary Policy Measures: Evidence from Survey Data." Federal Reserve Bank of New York Staff Report 752.

Andrés, Javier, J. David López-Salido, and Edward Nelson. 2004. "Tobin's Imperfect Asset Substitution in Optimizing General Equilibrium." *Journal of Money, Credit and Banking* 36 (4): 665-90.

Arteta, Carlos, M. Ayhan Kose, Marc Stoker, and Temel Taskin. 2016. "Negative Interest Rate Policies: Sources and Implications." Centre for Applied Macroeconomic Analysis Working Paper 52/2016.

Arteta, Carlos, M. Ayhan Kose, Marc Stocker, and Temel Taskin. 2018. "Implications of Negative Interest Rate Policies: An Early Assessment." *Pacific Economic Review* 23 (1): 8–26.

Auerbach, Alan J., and Maurice Obstfeld. 2005. "The Case for Open-Market Purchases in a Liquidity Trap." *American Economic Review* 95 (1): 110-37.

Bank of England. 2012. "News Release." July 13. https://www.bankofengland.co.uk/-/media/boe/files/news/2012/july/boe-and-hmt-announce-launch-of-funding-for-lending-scheme.

Bank of England. 2016. "Monetary Policy Summary." August 4. https://www.bankofengland.co.uk/monetary-policy-summary-and-minutes/2016/mpc-august-2016.

Bank of Japan. 2001. "New Procedures for Money Market Operations and Monetary Easing." March 19. https://www.boj.or.jp/en/announcements/release_2001/k010319a.htm/.

Bank of Japan. 2006. "Change in the Guideline for Money Market Operations." March 9. https://www.boj.or.jp/en/announcements/release_2006/k060309.htm/.

Bank of Japan. 2013. "Introduction of the 'Quantitative and Qualitative Monetary Easing'." April 4. https://www.boj.or.jp/en/announcements/release_2013/k130404a.pdf.

Bank of Japan. 2016. "New Framework for Strengthening Monetary Easing: 'Quantitative and Qualitative Monetary Easing with Yield Curve Control'." September 21. https://www.boj.or.jp/en/announcements/release_2016/k160921a.pdf.

Bank of Japan. 2018. "'Price Stability Target' of 2 Percent and 'Quantitative and Qualitative Monetary Easing with Yield Curve Control'." Outline of Monetary Policy. https://www.boj.or.jp/en/mopo/outline/qqe.htm/.

Bank of Japan. 2019. "Statement on Monetary Policy." April 25. https://www.boj.or.jp/en/announcements/release_2019/k190425a.pdf

Bank of Japan Monetary Affairs Department. 2010. "Fund-Provisioning Measure to Support Strengthening the Foundations for Economic Growth." *Bank of Japan Review* 2010-E-5. https://www.boj.or.jp/en/research/wps_rev/rev_2010/data/rev10e05.pdf.

Basten, Christoph, and Mike Mariathasan. 2018. "How Banks Respond to Negative Interest Rates: Evidence from the Swiss Exemption Threshold." CESifo Working Paper 6901.

Bauer, Michael D., and Christopher J. Neely. 2014. "International Channels of the Fed's Unconventional Monetary Policy." *Journal of International Money and Finance* 44: 24-46.

Bauer, Michael D., and Glenn D. Rudebusch. 2014. "The Signaling Channel for Federal Reserve Bond Purchases." *International Journal of Central Banking* 10 (3): 233-89.

Bauer, Michael D., and Glenn D. Rudebusch. 2016. "Monetary Policy Expectations at the Zero Lower Bound." *Journal of Money, Credit and Banking* 48 (7): 1439-65.

Baumeister, Christiane, and Luca Benati. 2013. "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound." *International Journal of Central Banking* 9 (2): 165-212.

Bean, Charles. 2009. "Monetary Policy Developments" Speech at Cutlers' Fest, Cutlers' Hall, Sheffield, May 21. https://www.bankofengland.co.uk/-/media/boe/files/speech/2009/charles-bean-speech-at-cutlers-fest.pdf.

Bech, Morten L., and Aytek Malkhozov. 2016. "How Have Central Banks Implemented Negative Policy Rates?" *BIS Quarterly Review* March: 31-44.

Beirne, John, et al. 2011. "The Impact of the Eurosystem's Covered Bond Purchase Programme on the Primary and Secondary Markets." European Central Bank Occasional Paper 122.

Bernanke, Ben S. 2012. "Opening Remarks: Monetary Policy Since the Onset of the Crisis." In *The Changing Policy Landscape*, 1-22. Proceedings of the Federal Reserve Bank of Kansas City Economic Policy Symposium, Jackson Hole, WY, August 30 – September 1.

Bernanke, Ben S. 2014. "A Conversation: The Fed Yesterday, Today, and Tomorrow." In *Central Banking after the Great Recession: Lessons Learned, Challenges Ahead*, edited by David Wessel, 5-20. Washington, D.C.: Brooking Institution Press.

Bernanke, Ben S. 2016. "What Tools Does the Fed Have Left? Part 2: Targeting Longer-Term Interest Rates." Brookings Institution. March 24. https://www.brookings.edu/blog/ben-bernanke/2016/03/24/what-tools-does-the-fed-have-left-part-2-targeting-longer-term-interest-rates/.

Bernanke, Ben S. 2020. "The New Tools of Monetary Policy." *American Economic Review* 110 (4): 943–83.

Bernanke, Ben S., Michael T. Kiley, and John M. Roberts. 2019. "Monetary Policy Strategies for a Low-Rate Environment." *AEA Papers and Proceedings* 109 (May): 421–26.

Bernanke, Ben S., and Vincent R. Reinhart. 2004. "Conducting Monetary Policy at Very Low Short-Term Interest Rates." *American Economic Review* 94 (2): 85-90.

Bernanke, Ben S., Vincent R. Reinhart, and Brian P. Sack. 2004. "Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment." *Brookings Papers on Economic Activity* 2004 (2): 1-78.

Betts, Caroline, and Michael B. Devereux. 2000. "Exchange Rate Dynamics in a Model of Pricing-to-Market." *Journal of International Economics* 50 (1): 215–44.

Betts, Caroline, and Michael B. Devereux. 2004. "The International Effects of Monetary and Fiscal Policy in a Two-Country Model." In *Money, Capital Mobility, and Trade: Essays in Honor of Robert A. Mundell*, edited by Guillermo A. Calvo, Rudiger Dornbusch, and Maurice Obstfeld, 9-52. Cambridge, MA: MIT Press.

Bhattarai, Saroj, Arpita Chatterjee, and Woong Yong Park. 2018. "Effects of U.S. Quantitative Easing on Emerging Market Economies." Asian Development Bank Institute Working Paper 803.

Bhattarai, Saroj, Gauti B. Eggertsson, and Bulat Gafarov. 2015. "Time Consistency and the Duration of Government Debt: A Signaling Theory of Quantitative Easing." National Bureau of Economic Research Working Paper 21336.

Bhattarai, Saroj, Gauti B. Eggertsson, and Bulat Gafarov. 2019. "Time Consistency and Duration of Government Debt: A Model of Quantitative Easing." https://sites.google.com/site/bhattaraisaroj/research. Accessed 2020-04-29.

Black, Fischer. 1995. "Interest Rates as Options." *Journal of Finance* 50 (5): 1371-6.

Boeckx, Jef, Maarten Dossche, and Gert Peersman. 2017. "Effectiveness and Transmission of the ECB's Balance Sheet Policies." *International Journal of Central Banking* 13 (1): 297-333.

Bottero, Margherita, Camelia Minoiu, José-Luis Peydro, Andrea Polo, Andrea F. Presbitero, and Enrico Sette. 2019. "Negative Monetary Policy Rates and Portfolio Rebalancing: Evidence from Credit Register Data." International Monetary Fund Working Paper 19/44.

Bowman, David, Fang Cai, Sally Davies, and Steven Kamin. 2015. "Quantitative Easing and Bank Lending: Evidence from Japan." *Journal of International Money and Finance* 57: 15-30.

Bowman, David, Juan M. Londono, and Horacio Sapriza. 2015. "U.S. Unconventional Monetary Policy and Transmission to Emerging Market Economies." *Journal of International Money and Finance* 55: 27-59.

Broadbent, Ben. 2018. "The History and Future of QE." Speech at the Society of Professional Economists, London, July 23. https://www.bankofengland.co.uk/speech/2018/ben-broadbent-society-of-professional-economists.

Brunner, Karl, and Allan H. Meltzer. 1973. "Mr. Hicks and the 'Monetarists'." *Economica* 40 (157): 44–59.

Brunnermeier, Markus K., and Yann Koby. 2018. "The Reversal Interest Rate." National Bureau of Economic Research Working Paper 25406.

Brunnermeier, Markus K., and Yuliy Sannikov. 2012. "Redistributive Monetary Policy." Jackson Hole Symposium Paper 2013331-384.

Brunnermeier, Markus K., and Yuliy Sannikov. 2016. "The I Theory of Money." National Bureau of Economic Research Working Paper 22533.

Bua, Giovanna and Peter G. Dunne. 2019. "The Portfolio Rebalancing Effects of the ECB's Asset Purchase Programme." Central Bank of Ireland Research Technical Paper 07/RT/17.

Bullard, James. 2010. "Three Lessons for Monetary Policy from the Panic of 2008." *Federal Reserve Bank of St. Louis Review* 92 (3): 155-63.

Bundick, Brent, and A. Lee Smith. Forthcoming. "The Dynamic Effects of Forward Guidance Shocks." *Review of Economics and Statistics*.

Butt, Nicholas, Rohan Churm, Michael McMahon, Arpad Morotz, and Jochen Schanz. 2015. "QE and the Bank Lending Channel in the United Kingdom." Centre for Macroeconomics Discussion Paper 2015-23.

Caballero, Ricardo J., Takeo Hoshi, and Anil K. Kashyap. 2008. "Zombie Lending and Depressed Restructuring in Japan." *American Economic Review* 98 (5): 1943-77.

Cahill, Michael, Stefania D'Amico, Canlin Li, and John Sears. 2013. "Duration Risk versus Local Supply Channel in Treasury Yields: Evidence from the Federal Reserve's Asset Purchase Announcements." Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2013-35.

Cahn, Christophe, Julien Matheron, and Jean-Guillaume Sahuc. 2017. "Assessing the Macroeconomic Effects of LTROs during the Great Recession." *Journal of Money, Credit and Banking* 49 (7): 1443-82.

Campbell, Jeffrey R., Charles L. Evans, Jonas D. M. Fisher, and Alejandro Justiniano. 2012. "Macroeconomic Effects of Federal Reserve Forward Guidance." *Brookings Papers on Economic Activity* 2012 (1): 1-54.

Campbell, John Y., and Samuel B. Thompson. 2008. "Predicting Excess Stock Returns out of Sample: Can Anything Beat the Historical Average?" *Review of Financial Studies* 21 (4): 1509–31.

Carlstrom, Charles T., Timothy S. Fuerst, and Matthias Paustian. 2017. "Targeting Long Rates in a Model with Segmented Markets." *American Economic Journal: Macroeconomics* 9 (1): 205–42.

Carney, Mark. 2016. "The Spectre of Monetarism." Roscoe Lecture at Liverpool John Moores University, Liverpool, December 5. https://www.bankofengland.co.uk/-/media/boe/files/speech/2016/the-spectre-of-monetarism.pdf.

Carney, Mark. 2017. Letter to Philip Hammond, Chancellor of the Exchequer, November 20. https://www.bankofengland.co.uk/-/media/boe/files/letter/2017/governor-tfs-letter-201117.pdf?la=en&hash=DF9A241D0E397CF290040ECBEAD0EC0C206B794D.

Carpenter, Seth, Selva Demiralp, Jane Ihrig, and Elizabeth Klee. 2015. "Analyzing Federal Reserve Asset Purchases: From Whom Does the Fed Buy?" *Journal of Banking and Finance* 52: 230-44.

Chadha, Jagjit S., Philip Turner, and Fabrizio Zampolli. 2013. "The Interest Rate Effects of Government Debt Maturity." BIS Working Paper 415.

Chakraborty, Indraneel, Itay Goldstein, and Andrew MacKinlay. 2020. "Monetary Stimulus and Bank Lending." *Journal of Financial Economics* 136 (1): 189-218.

Chen, Han, Vasco Cúrdia, and Andrea Ferrero. 2012. "The Macroeconomic Effects of Large-Scale Asset Purchase Programmes." *Economic Journal* 122 (564): F289-315.

Chen, Qianying, Andrew Filardo, Dong He, and Feng Zhu. 2016. "Financial Crisis, U.S. Unconventional Monetary Policy and International Spillovers." *Journal of International Money and Finance* 67: 62-81.

Chodorow-Reich, Gabriel. 2014. "Effects of Unconventional Monetary Policy on Financial Institutions." *Brookings Papers on Economic Activity* 2014 (1): 155-204.

Christensen, Jens H. E., and Signe Krogstrup. 2019. "Transmission of Quantitative Easing: The Role of Central Bank Reserves." *Economic Journal* 129 (617): 249-72.

Christensen, Jens H. E., and Glenn D. Rudebusch. 2012. "The Response of Interest Rates to U.S. and U.K. Quantitative Easing." *Economic Journal* 122 (564): F385-414.

Christensen, Jens H. E., and Mark M. Spiegel. 2019. "Assessing Abenomics: Evidence from Inflation-Indexed Japanese Government Bonds." Federal Reserve Bank of San Francisco Working Paper 2019-15.

Churm, Rohan, Jeremy Leake, Amar Radia, Sylaja Srinivasan, and Richard Whisker. 2012. "The Funding for Lending Scheme." *Bank of England Quarterly Bulletin* 52 (4): 306-20.

Cieslak, Anna, and Andreas Schrimpf. 2019. "Non-Monetary News in Central Bank Communication." *Journal of International Economics* 118: 293–315.

Claus, Edda, Iris Claus, and Leo Krippner. 2018. "Asset Market Responses to Conventional and Unconventional Monetary Policy Shocks in the United States." *Journal of Banking and Finance* 97: 270-82.

Correia-Golay, Ellen, Steven Friedman, and Michael McMorrow. 2013. "Understanding the New York Fed's Survey of Primary Dealers." *Federal Reserve Bank of New York Current Issues in Economics and Finance* 19 (6): 1-8.

Corsetti, Giancarlo, and Luca Dedola. 2016. "The Mystery of the Printing Press: Monetary Policy and Self-Fulfilling Debt Crises." *Journal of the European Economic Association* 14 (6): 1329–71.

Cœuré, Benoît. 2013. “Outright Monetary Transactions, One Year On.” Speech at “The ECB and its OMT Programme” Conference, Berlin, September 2. https://www.ecb.europa.eu/press/key/date/2013/html/sp130902.en.html.

Crosignani, Matteo, Miguel Faria-e-Castro, and Luís Fonseca. Forthcoming. “The (Unintended?) Consequences of the Largest Liquidity Injection Ever.” *Journal of Monetary Economics*.

Culbertson, John M. 1957. “The Term Structure of Interest Rates.” *Quarterly Journal of Economics* 71 (4): 485-517.

Cúrdia, Vasco, and Michael Woodford. 2011. “The Central-Bank Balance Sheet as an Instrument of Monetary Policy.” *Journal of Monetary Economics* 58 (1): 54-79.

D’Amico, Stefania, and Thomas B. King. 2013. “Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply.” *Journal of Financial Economics* 108 (2): 425-48.

Darracq-Paries, Matthieu, and Roberto A. De Santis. 2015. “A Non-Standard Monetary Policy Shock: The ECB’s 3-Year LTROs and the Shift in Credit Supply.” *Journal of International Money and Finance* 54: 1-34.

De Pooter, Michiel, Robert F. Martin, and Seth Pruitt. 2018. “The Liquidity Effects of Official Bond Market Intervention.” *Journal of Financial and Quantitative Analysis* 53 (1): 243–68.

De Rezende, Rafael B. 2017. “The Interest Rate Effects of Government Bond Purchases Away from the Lower Bound.” *Journal of International Money and Finance* 74: 165-86.

De Santis, Roberto A. 2020. “Impact of the Asset Purchase Programme on Euro Area Government Bond Yields Using Market News.” *Economic Modelling* 86: 192–209.

Debortoli, Davide, Jordi Galí, and Luca Gambetti. 2019. “On the Empirical (Ir)Relevance of the Zero Lower Bound Constraint.” National Bureau of Economic Research Working Paper 25820.

Del Negro, Marco, Gauti Eggertsson, Andrea Ferrero, and Nobuhiro Kiyotaki. 2017. “The Great Escape? A Quantitative Evaluation of the Fed’s Liquidity Facilities.” *American Economic Review* 107 (3): 824–57.

Del Negro, Marco, Marc P. Giannoni, and Christina Patterson. 2015. “The Forward Guidance Puzzle.” Federal Reserve Bank of New York Staff Report 574.

Di Maggio, Marco, Amir Kermani, and Christopher J. Palmer. 2020. “How Quantitative Easing Works: Evidence on the Refinancing Channel.” *Review of Economic Studies* 87 (3): 1498-528.

Dornbusch, Rudiger. 1976. “Exchange Rate Expectations and Monetary Policy.” *Journal of International Economics* 6 (3): 231-44.

Draghi, Mario. 2014a. "Introductory Statement to the Press Conference (with Q&A)." European Central Bank Governing Council Press Conference, Frankfurt am Main, June 5. https://www.ecb.europa.eu/press/pressconf/2014/html/is140605.en.html.

Draghi, Mario. 2014b. "Introductory Statement to the Press Conference (with Q&A)." European Central Bank Governing Council Press Conference, Frankfurt am Main, September 4. https://www.ecb.europa.eu/press/pressconf/2014/html/is140904.en.html.

Draghi, Mario. 2015a. "The ECB's Recent Monetary Policy Measures: Effectiveness and Challenges." The Michel Camdessus Central Banking Lecture at the International Monetary Fund, Washington, D.C., May 14. https://www.ecb.europa.eu/press/key/date/2015/html/sp150514.en.html.

Draghi, Mario. 2015b. "Monetary Policy: Past, Present and Future." Speech at the Frankfurt European Banking Congress, Frankfurt am Main, November 20. https://www.ecb.europa.eu/press/key/date/2015/html/sp151120.en.html.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl. 2017. "The Deposits Channel of Monetary Policy." *Quarterly Journal of Economics* 132 (4): 1819–76.

Duffie, Darrell. 2010. "Presidential Address: Asset Price Dynamics with Slow-Moving Capital." *Journal of Finance* 65 (4): 1237–67.

Eberly, Janice C., James H. Stock, and Jonathan H. Wright. 2019. "The Federal Reserve's Current Framework for Monetary Policy: A Review and Assessment." National Bureau of Economic Research Working Paper 26002.

Eggertsson, Gauti B., and Michael Woodford. 2003. "The Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* 2003 (1): 139-211.

Eggertsson, Gauti B., Ragnar E. Juelsrud, Lawrence H. Summers, and Ella Getz Wold. 2019. "Negative Nominal Interest Rates and the Bank Lending Channel." National Bureau of Economic Research Working Paper 25416.

Ehrmann, Michael and Marcel Fratzscher. 2004. "Taking Stock: Monetary Policy Transmission to Equity Markets." *Journal of Money, Credit and Banking* 36 (4): 719-37.

Eser, Fabian, and Bernd Schwaab. 2016. "Evaluating the Impact of Unconventional Monetary Policy Measures: Empirical Evidence from the ECB's Securities Market Programme." *Journal of Financial Economics* 119 (1): 147-67.

European Central Bank. 2010. "Press Release." May 10. https://www.ecb.europa.eu/press/pr/date/2010/html/pr100510.en.html.

European Central Bank. 2012. "Press Release." October 31. https://www.ecb.europa.eu/press/pr/date/2012/html/pr121031_1.en.html.

European Central Bank. 2014. "The ECB's Negative Interest Rate." European Central Bank Explainers, June 12. https://www.ecb.europa.eu/explainers/tell-me-more/html/why-negative-interest-rate.en.html.

European Central Bank. 2017. "The ECB's Corporate Sector Purchase Programme: Its Implementation and Impact." *European Central Bank Economic Bulletin* 2017 (4): 40-45.

European Central Bank. 2018. "Press Release." June 14. https://www.ecb.europa.eu/press/pr/date/2018/html/ecb.mp180614.en.html.

Fama, Eugene. 2013. "Nobel Prize Winner on QE." Interview by Rick Santelli. *The Santelli Exchange*, CNBC, October 29. https://www.cnbc.com/video/2013/10/29/nobel-prize-winner-on-qe.html.

Farmer, Roger E. A. 2012. "The Effect of Conventional and Unconventional Monetary Policy Rules on Inflation Expectations: Theory and Evidence." *Oxford Review of Economic Policy* 28 (4): 622-39.

Farmer, Roger E. A. 2013. "Qualitative Easing: A New Tool for the Stabilisation of Financial Markets." The John Flemming Memorial Lecture *Bank of England Quarterly Bulletin* 2013 (4): 405-13.

Farmer, Roger E. A., and Pawel Zabczyk. 2016. "The Theory of Unconventional Monetary Policy." National Bureau of Economic Research Working Paper 22135.

Faust, Jon, John H. Rogers, and Jonathan H. Wright. 2003. "Exchange Rate Forecasting: The Errors We've Really Made." *Journal of International Economics* 60 (1): 35–59.

Fawley, Brett W., and Christopher J. Neely. 2014. "The Evolution of Federal Reserve Policy and the Impact of Monetary Policy Surprises on Asset Prices." *Federal Reserve Bank of St. Louis Review* 96 (1): 73-109.

Femia, Katherine, Steven Friedman, and Brian Sack. 2013. "The Effects of Policy Guidance on Perceptions of the Fed's Reaction Function." Federal Reserve Bank of New York Staff Report 652.

Feroli, Michael, David Greenlaw, Peter Hooper, Frederic S. Mishkin, and Amir Sufi. 2017. "Language after Liftoff: Fed Communication Away from the Zero Lower Bound." *Research in Economics* 71 (3): 452-90.

Fischer, Stanley. 2014. "The Great Recession: Moving Ahead." Speech at "The Great Recession – Moving Ahead" Conference, Stockholm, August 11. https://www.federalreserve.gov/newsevents/speech/fischer20140811a.htm.

Fischer, Stanley. 2016. "Longer-Term Challenges for the U.S. Economy." Speech at "A Conversation with Stanley Fischer," New York, November 21. https://www.federalreserve.gov/newsevents/speech/fischer20161121a.htm.

Foerster, Andrew, and Guangye Cao. 2013. "Expectations of Large-Scale Asset Purchases." *Federal Reserve Bank of Kansas City Economic Review* 2013 (2): 5-29.

Forbes, Kristin, Dennis Reinhardt, and Tomasz Wieladek. 2017. "The Spillovers, Interactions, and (Un)Intended Consequences of Monetary and Regulatory Policies." *Journal of Monetary Economics* 85: 1-22.

Frankel, Jeffrey A., and Andrew K. Rose. 1996. "Currency Crashes in Emerging Markets: An Empirical Treatment." *Journal of International Economics* 41 (3-4): 351–66.

Fratzscher, Marcel, Marco Lo Duca, and Roland Straub. 2016. "ECB Unconventional Monetary Policy: Market Impact and International Spillovers." *IMF Economic Review* 64 (1): 36-74.

Fratzscher, Marcel, Marco Lo Duca, and Roland Straub. 2018. "On the International Spillovers of US Quantitative Easing." *Economic Journal* 128 (608): 330-77.

Friedman, Benjamin M. 1978. "Crowding Out or Crowding In? Economic Consequences of Financing Government Deficits." *Brookings Papers on Economic Activity* 1978 (3): 593–641.

Fuhrer, Jeffrey C., and Giovanni R Olivei. 2011. "The Estimated Macroeconomic Effects the Federal Reserve's Large-Scale Treasury Purchase Program." Federal Reserve Bank of Boston Public Policy Brief 11-2.

Fukuda, Shin-ichi. 1993. "International Transmission of Monetary and Fiscal Policy: A Symmetric N-Country Analysis with Union." *Journal of Economic Dynamics and Control* 17 (4): 589–620.

Fukuda, Shin-ichi. 2015. "Abenomics: Why Was It so Successful in Changing Market Expectations?" *Journal of the Japanese and International Economies* 37: 1–20.

Fukuda, Shin-Ichi. 2017. "Spillover Effects of Japan's Quantitative and Qualitative Easing on East Asian Economies." Asian Development Bank Institute Working Paper 631.

Fuster, Andreas, and Paul S. Willen. 2010. "$1.25 Trillion Is Still Real Money: Some Facts about the Effects of the Federal Reserve's Mortgage Market Investments." Federal Reserve Bank of Boston Public Policy Discussion Paper 10-4.

Gabaix, Xavier, Arvind Krishnamurthy, and Olivier Vigneron. 2007. "Limits of Arbitrage: Theory and Evidence from the Mortgage-Backed Securities Market." *Journal of Finance* 62 (2): 557–95.

Gagnon, Joseph. 2016. "Quantitative Easing: An Underappreciated Success." Peterson Institute for International Economics Policy Brief 16-4.

Gagnon, Joseph. 2018. "QE Skeptics Overstate Their Case." *Peterson Institute for International Economics Realtime Economic Issues Watch*, July 5. https://piie.com/blogs/realtime-economic-issues-watch/qe-skeptics-overstate-their-case.

Gagnon, Joseph, Matthew Raskin, Julie Remache, and Brian Sack. 2011. "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases." *International Journal of Central Banking* 7 (1): 3-43.

Gambacorta, Leonardo, Boris Hofmann, and Gert Peersman. 2014. "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis." *Journal of Money, Credit and Banking* 46 (4): 615-42.

Garín, Julio, Robert Lester, and Eric Sims. 2019. "Are Supply Shocks Contractionary at the ZLB? Evidence from Utilization-Adjusted TFP Data." *Review of Economics and Statistics* 101 (1): 160–75.

Georgiadis, Georgios, and Johannes Gräb. 2016. "Global Financial Market Impact of the Announcement of the ECB's Asset Purchase Programme." *Journal of Financial Stability* 26: 257–65.

Gertler, Mark, and Peter Karadi. 2011. "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics* 58 (1): 17-34.

Gertler, Mark, and Peter Karadi. 2013. "QE 1 vs. 2 vs. 3…: A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool." *International Journal of Central Banking* 9 (S1): 5-53.

Gertler, Mark, and Nobu Kiyotaki. 2010. "Financial Intermediation and Credit Policy in Business Cycle Analysis." In *Handbook of Monetary Economics, Volume 3*, edited by Benjamin M. Friedman and Michael Woodford, 547–99. Amsterdam: Elsevier, North-Holland.

Ghysels, Eric, Julien Idier, Simone Manganelli, and Olivier Vergote. 2017. "A High-Frequency Assessment of the ECB Securities Markets Programme." *Journal of the European Economic Association* 15 (1): 218-43.

Gilchrist, Simon, and Egon Zakrajšek. 2013. "The Impact of the Federal Reserve's Large-Scale Asset Purchase Programs on Corporate Credit Risk." *Journal of Money, Credit and Banking* 45 (2): 29-57.

Greenlaw, David, James D. Hamilton, Ethan Harris, and Kenneth D. West. 2018. "A Skeptical View of the Impact of the Fed's Balance Sheet." National Bureau of Economic Research Working Paper 24687.

Greenwood, Robin, Samuel G. Hanson, and Gordon Y. Liao. 2018. “Asset Price Dynamics in Partially Segmented Markets.” *Review of Financial Studies* 31 (9): 3307-43.

Greenwood, Robin, Samuel G. Hanson, Joshua S. Rudolph, and Lawrence H. Summers. 2014. “Government Debt Management at the Zero Lower Bound.” Brookings Institution Hutchins Center on Fiscal and Monetary Policy Working Paper 5.

Greenwood, Robin, and Dimitri Vayanos. 2010. “Price Pressure in the Government Bond Market.” *American Economic Review* 100 (2): 585–90.

Greenwood, Robin, and Dimitri Vayanos. 2014. “Bond Supply and Excess Bond Returns.” *Review of Financial Studies* 27 (3): 663–713.

Guidolin, Massimo, and Christopher J. Neely. 2010. “The Effects of Large-Scale Asset Purchases on TIPS Inflation Expectations.” *Federal Reserve Bank of St. Louis Economic Synopses* 2010 (26).

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson. 2005. “Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements.” *International Journal of Central Banking* 1(1): 55-93.

Haas, Jacob, Christopher J. Neely, and William R. Emmons. Forthcoming. “Responses of International Central Banks to the COVID-19 Crisis.” *Federal Reserve Bank of St. Louis Review*.

Hamilton, James D. 2018. “The Efficacy of Large-Scale Asset Purchases When the Short-Term Interest Rate Is at Its Effective Lower Bound.” *Brookings Papers on Economic Activity* 2018 (2): 543–54.

Hamilton, James D. and Jing Cynthia Wu. 2012. “The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment.” *Journal of Money, Credit and Banking* 44 (1): 3-46.

Hancock, Diana, and Wayne Passmore. 2011. “Did the Federal Reserve’s MBS Purchase Program Lower Mortgage Rates?” *Journal of Monetary Economics* 58 (5): 498-514.

Harrison, Richard. 2012. “Asset Purchase Policy at the Effective Lower Bound for Interest Rates.” Bank of England Working Paper 444.

Hattori, Masazumi, Andreas Schrimpf, and Vladyslav Sushko. 2016. “The Response of Tail Risk Perceptions to Unconventional Monetary Policy.” *American Economic Journal: Macroeconomics* 8 (2): 111-36.

Hayashi, Fumio, and Junko Koeda. 2019. “Exiting from Quantitative Easing.” *Quantitative Economics* 10 (3): 1069–107.

Heider, Florian, Farzad Saidi, and Glenn Schepens. 2019. "Life below Zero: Bank Lending under Negative Policy Rates." *Review of Financial Studies* 32 (10): 3728–61.

Hoshi, Takeo. 2006. "Economics of the Living Dead." *Japanese Economic Review* 57 (1): 30-49.

Hubert, Paul, and Fabien Labondance. 2018. "The Effect of ECB Forward Guidance on the Term Structure of Interest Rates." *International Journal of Central Banking* 14 (5): 193-222.

Ihrig, Jane, Elizabeth Klee, Canlin Li, Min Wei, and Joe Kachovec. 2018. "Expectations about the Federal Reserve's Balance Sheet and the Term Structure of Interest Rates." *International Journal of Central Banking* 14 (2): 341-90.

International Monetary Fund. 2017. "Negative Interest Rate Policies – Initial Experiences and Assessments." IMF Policy Paper.

Inoue, Atsushi, and Barbara Rossi. 2018. "The Effects of Conventional and Unconventional Monetary Policy on Exchange Rates." National Bureau of Economic Research Working Paper 25021.

Ippolito, Filippo, Ali K. Ozdagli, and Ander Perez-Orive. 2018. "The Transmission of Monetary Policy through Bank Lending: The Floating Rate Channel." *Journal of Monetary Economics* 95: 49-71.

Ito, Takatoshi, and Frederic S. Mishkin. 2006. "Two Decades of Japanese Monetary Policy and the Deflation Problem." In *Monetary Policy under Very Low Inflation in the Pacific Rim, National Bureau of Economic Research – East Asia Seminar on Economics, Volume 15*, edited by Takatoshi Ito and Andrew K. Rose, 131-93. Chicago: University of Chicago Press.

Jäger, Jannik, and Theocharis Grigoriadis. 2017. "The Effectiveness of the ECB's Unconventional Monetary Policy: Comparative Evidence from Crisis and Non-Crisis Euro-Area Countries." *Journal of International Money and Finance* 78: 21-43.

Jobst, Andreas, and Huidan Lin. 2016. "Negative Interest Rate Policy (NIRP): Implications for Monetary Transmission and Bank Profitability in the Euro Area." International Monetary Fund Working Paper 16/172.

Joyce, Michael A. S., Ana Lasaosa, Ibrahim Stevens, and Matthew Tong. 2011. "The Financial Market Impact of Quantitative Easing in the United Kingdom." *International Journal of Central Banking* 7 (3): 113-61.

Joyce, Michael A. S., Zhuoshi Liu, and Ian Tonks. 2017. "Institutional Investors and the QE Portfolio Balance Channel." *Journal of Money, Credit and Banking* 49 (6): 1225-46.

Joyce, Michael A. S., Nick McLaren, and Chris Young. 2012. "Quantitative Easing in the United Kingdom: Evidence from Financial Markets on QE1 and QE2." *Oxford Review of Economic Policy* 28 (4): 671-701.

Joyce, Michael A. S., and Marco Spaltro. 2014. "Quantitative Easing and Bank Lending: A Panel Data Approach." Bank of England Working Paper 504.

Joyce, Michael A. S., Matthew Tong, and Robert Woods. 2011. "The United Kingdom's Quantitative Easing Policy: Design, Operation and Impact." *Bank of England Quarterly Bulletin* 51 (3): 200-12.

Jung, Taehun, Yuki Teranishi, and Tsutomu Watanabe. 2005. "Optimal Monetary Policy at the Zero-Interest-Rate Bound." *Journal of Money, Credit and Banking* 37 (5): 813-35.

Kapetanios, George, Haroon Mumtaz, Ibrahim Stevens, and Konstantinos Theodoridis. 2012. "Assessing the Economy-Wide Effects of Quantitative Easing." *Economic Journal* 122 (564): F316-47.

Kashyap, Anil K., and Jeremy C. Stein. 1994. "The Impact of Monetary Policy on Bank Balance Sheets." National Bureau of Economic Research Working Paper 4821.

Kashyap, Anil K., and Jeremy C. Stein. 2000. "What Do a Million Observations on Banks Say about the Transmission of Monetary Policy?" *American Economic Review* 90 (3): 407-28.

Kettemann, Andreas, and Signe Krogstrup. 2014. "Portfolio Balance Effects of the Swiss National Bank's Bond Purchase Program." *Journal of Macroeconomics* 40: 132-49.

Kiley, Michael T. 2014. "The Response of Equity Prices to Movements in Long-Term Interest Rates Associated with Monetary Policy Statements: Before and After the Zero Lower Bound." *Journal of Money, Credit and Banking* 46 (5): 1057-71.

Kiley, Michael T. 2016. "Monetary Policy Statements, Treasury Yields, and Private Yields: Before and After the Zero Lower Bound." *Finance Research Letters* 18: 285-90.

Kimura, Takeshi, and David H. Small. 2006. "Quantitative Easing and Risk in Financial Asset Markets." *B.E. Journal of Macroeconomics* 6 (1): 1-54.

Kobayashi, Takeshi, Mark M. Spiegel, and Nobuyoshi Yamori. 2006. "Quantitative Easing and Japanese Bank Equity Values." *Journal of the Japanese and International Economies* 20 (4): 699-721.

Koijen, Ralph S. J., François Koulischer, Benoît Nguyen, and Motohiro Yogo. 2017. "Euro-Area Quantitative Easing and Portfolio Rebalancing." *American Economic Review: Papers & Proceedings* 107 (5): 621–27.

Kortela, Tomi. 2016. "A Shadow Rate Model with Time-Varying Lower Bound of Interest Rates." Bank of Finland Research Discussion Paper 19/2016.

Krippner, Leo. 2013a. "Measuring the Stance of Monetary Policy in Zero Lower Bound Environments." *Economics Letters* 118 (1): 135-38.

Krippner, Leo. 2013b. “A Tractable Framework for Zero-Lower-Bound Gaussian Term Structure Models.” Centre for Applied Macroeconomic Analysis Working Paper 49/2013.

Krishnamurthy, Arvind, Stefan Nagel, and Annette Vissing-Jorgensen. 2017. “ECB Policies Involving Government Bond Purchases: Impact and Channels.” *Review of Finance* 22 (1): 1-44.

Krishnamurthy, Arvind, and Annette Vissing-Jorgensen. 2011. “The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy.” *Brookings Papers on Economic Activity* 2011 (2): 215-65.

Krugman, Paul R. 1998. “It’s Baaack: Japan’s Slump and the Return of the Liquidity Trap.” *Brookings Papers on Economic Activity* 1998 (2): 137-206.

Kurtzman, Robert, Stephan Luck, and Tom Zimmermann. Forthcoming. “Did QE Lead Banks to Relax Their Lending Standards? Evidence from the Federal Reserve’s LSAPs.” *Journal of Banking and Finance*.

Kuttner, Kenneth N. 2001. “Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market.” *Journal of Monetary Economics* 47 (3): 523-44.

Kuttner, Kenneth N. 2018. “Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond.” *Journal of Economic Perspectives* 32 (4): 121–46.

Laubach, Thomas, and John C. Williams. 2016. “Measuring the Natural Rate of Interest Redux.” *Business Economics* 51 (2): 57-67.

Lemke, Wolfgang, and Andreea Liliana Vladu. 2017. “Below the Zero Lower Bound: A Shadow-Rate Term Structure Model for the Euro Area.” European Central Bank Working Paper 1991.

Li, Canlin, and Min Wei. 2013. “Term Structure Modeling with Supply Factors and the Federal Reserve’s Large-Scale Asset Purchase Programs.” *International Journal of Central Banking* 9 (1): 3-39.

Lim, Jamus Jerome, and Sanket Mohapatra. 2016. “Quantitative Easing and the Post-Crisis Surge in Financial Flows to Developing Countries.” *Journal of International Money and Finance* 68: 331-57.

Lo Duca, Marco, Giulio Nicoletti, and Ariadna Vidal Martínez. 2016. “Global Corporate Bond Issuance: What Role for US Quantitative Easing?” *Journal of International Money and Finance* 60: 114-50.

Lopez, Jose A., Andrew K. Rose, and Mark M. Spiegel. 2020. “Why Have Negative Nominal Interest Rates Had Such a Small Effect on Bank Performance? Cross Country Evidence.” *European Economic Review* 124: 103402.

Lucas, Robert E., Jr., and Nancy L. Stokey. 1983. "Optimal Fiscal and Monetary Policy in an Economy without Capital." *Journal of Monetary Economics* 12 (1): 55–93.

Mamaysky, Harry. 2018. "The Time Horizon of Price Responses to Quantitative Easing." *Journal of Banking and Finance* 90: 32-49.

Martin, Christopher, and Costas Milas. 2012. "Quantitative Easing: A Sceptical Survey." *Oxford Review of Economic Policy* 28 (4): 750-64.

Matousek, Roman, Stephanos T. Papadamou, Aleksandar Šević, and Nickolaos G. Tzeremes. 2019. "The Effectiveness of Quantitative Easing: Evidence from Japan." *Journal of International Money and Finance* 99: 102068.

McCauley, Robert N., and Kazuo Ueda. 2009. "Government Debt Management at Low Interest Rates." *BIS Quarterly Review* June: 35-51.

McInish, Thomas, Christopher J. Neely, and Jade Planchon. 2019. "Unconventional Monetary Policy and the Behavior of Shorts." Federal Reserve Bank of St. Louis Working Paper 2017-031H.

McLaren, Nick, Ryan N. Banerjee, and David Latto. 2014. "Using Change in Auction Maturity Sectors to Help Identify the Impact of QE on Gilt Yields." *Economic Journal* 124 (576): 453-79.

Modigliani, Franco and Richard Sutch. 1966. "Innovations in Interest Rate Policy." *American Economic Review* 56 (1/2): 178-97.

Molyneux, Philip, Alessio Reghezza, and Ru Xie. 2019. "Bank Margins and Profits in a World of Negative Rates." *Journal of Banking & Finance* 107: 105613.

Mouabbi, Sarah, and Jean-Guillaume Sahuc. 2019. "Evaluating the Macroeconomic Effects of the ECB's Unconventional Monetary Policies." *Journal of Money, Credit and Banking* 51 (4): 831–58.

Nakamura, Emi, and Jón Steinsson. 2018. "High-Frequency Identification of Monetary Non-Neutrality: The Information Effect." *Quarterly Journal of Economics* 133 (3): 1283–330.

Nakaso, Hiroshi. 2017. "Evolving Monetary Policy: The Bank of Japan's Experience." Speech at the Federal Reserve Bank of New York Central Banking Seminar, October 18. https://www.boj.or.jp/en/announcements/press/koen_2017/data/ko171019a1.pdf.

Neely, Christopher J. 2014. "Lessons from the Taper Tantrum." Federal Reserve Bank of St. Louis *Economic Synopses* 2014 (2).

Neely, Christopher J. 2015. "Unconventional Monetary Policy Had Large International Effects." *Journal of Banking and Finance* 52: 101-11.

Neely, Christopher J. 2016. “How Persistent Are Unconventional Monetary Policy Effects?” Federal Reserve Bank of St. Louis Working Paper 2014-004C.

Neely, Christopher J., and Evan Karson. Forthcoming. “More Stories of Unconventional Monetary Policy.” *Federal Reserve Bank of St. Louis Review*.

Nucera, Federico, André Lucas, Julia Schaumburg, and Bernd Schwaab. 2017. “Do Negative Interest Rates Make Banks Less Safe?” *Economics Letters* 159: 112–15.

Obstfeld, Maurice, and Kenneth Rogoff. 1995. “Exchange Rate Dynamics Redux.” *Journal of Political Economy* 103 (3): 624–60.

Okina, Kunio, and Shigenori Shiratsuka. 2004. “Policy Commitment and Expectation Formation: Japan’s Experience under Zero Interest Rates.” *North American Journal of Economics and Finance* 15 (1): 75-100.

Pasquariello, Paolo, Jennifer Roush, and Clara Vega. 2020. “Government Intervention and Strategic Trading in the U.S. Treasury Market.” *Journal of Financial and Quantitative Analysis* 55 (1): 117–57.

Powell, Jerome H. 2013. “Thoughts on Unconventional Monetary Policy.” Speech at the Bipartisan Policy Center, Washington, D.C., June 27. https://www.federalreserve.gov/newsevents/speech/powell20130627a.htm.

Powell, Jerome H. 2019. “Monetary Policy: Normalization and the Road Ahead.” Speech at the 2019 SIEPR Economic Summit, Stanford, California, March 8. https://www.federalreserve.gov/newsevents/speech/powell20190308a.htm

Raskin, Matthew. 2013. “The Effects of the Federal Reserve’s Date-Based Forward Guidance.” Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2013-37.

Reifschneider, David L. 2016. “Gauging the Ability of the FOMC to Respond to Future Recessions.” Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2016-068.

Rodnyansky, Alexander, and Olivier M. Darmouni. 2017. “The Effects of Quantitative Easing on Bank Lending Behavior.” *Review of Financial Studies* 30 (11): 3858-87.

Rognlie, Matthew. 2016. “What Lower Bound? Monetary Policy with Negative Interest Rates.” http://mattrognlie.com/negative_rates.pdf. Accessed on 2020-04-29.

Rogoff, Kenneth. 2017. “Dealing with Monetary Paralysis at the Zero Bound.” *Journal of Economic Perspectives* 31 (3): 47–66.

Schenkelberg, Heike, and Sebastian Watzka. 2013. "Real Effects of Quantitative Easing at the Zero-Lower Bound: Structural VAR-Based Evidence from Japan." *Journal of International Money and Finance* 33: 327-57.

Shin, Hyun Song. 2016. "Bank Capital and Monetary Policy Transmission." Panel Remarks at the ECB and its Watchers XVII Conference, Frankfurt, April 7. https://www.bis.org/speeches/sp160407.pdf.

Sims, Eric R, and Jing Cynthia Wu. 2019a. "Evaluating Central Banks' Tool Kit: Past, Present, and Future." National Bureau of Economic Research Working Paper 26040.

Sims, Eric R, and Jing Cynthia Wu. 2019b. "The Four Equation New Keynesian Model." National Bureau of Economic Research Working Paper 26067.

Stroebel, Johannes, and John B. Taylor. 2012. "Estimated Impact of the Federal Reserve's Mortgage-Backed Securities Purchase Program." *International Journal of Central Banking* 8 (2): 1-42.

Swanson, Eric T. 2019. "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets." http://www.socsci.uci.edu/~swanson2/papers/facts3.pdf. Accessed on 2020-04-29.

Szczerbowicz, Urszula. 2015. "The ECB Unconventional Monetary Policies: Have They Lowered Market Borrowing Costs for Banks and Governments?" *International Journal of Central Banking* 11 (4): 91-127.

Timiraos, Nick. 2017. "Fed Raises Rates, Set Out Plan to Shrink Asset Holdings Beginning This Year." *Wall Street Journal*, June 14. https://www.wsj.com/articles/fed-raises-rates-sets-out-plan-to-shrink-asset-holdings-beginning-this-year-1497463322.

Thornton, Daniel L. 2014. "QE: Is There a Portfolio Balance Effect?" *Federal Reserve Bank of St. Louis Review* 96 (1): 55-72.

Tobin, James. 1958. "Liquidity Preference as Behavior Towards Risk." *Review of Economic Studies* 25 (2): 65-86.

Tobin, James. 1969. "A General Equilibrium Approach to Monetary Theory." *Journal of Money, Credit, and Banking* 1 (1): 15-29.

Trichet, Jean-Claude. 2009. "The Financial Crisis and the Role of Central Banks: The Experience of the ECB." Speech at the International Symposium Marking the 50th Anniversary of Bank Al-Maghrib, Marrakech, May 29. https://www.ecb.europa.eu/press/key/date/2009/html/sp090529.en.html.

Turnovsky, Stephen J. 1986. "Monetary and Fiscal Policy under Perfect Foresight: A Symmetric Two-Country Analysis." *Economica* 53 (210): 139–57.

Ugai, Hiroshi. 2007. "Effects of the Quantitative Easing Policy: A Survey of Empirical Analyses." *Bank of Japan Monetary and Economic Studies* 25 (1): 1–48.

Ulate, Mauricio. 2019. "Going Negative at the Zero Lower Bound: The Effects of Negative Nominal Interest Rates." Federal Reserve Bank of San Francisco Working Paper 2019-21.

Vayanos, Dimitri, and Jean-Luc Vila. 2009. "A Preferred-Habitat Model of the Term Structure of Interest Rates." National Bureau of Economic Research Working Paper 15487.

Walentin, Karl. 2014. "Business Cycle Implications of Mortgage Spreads." *Journal of Monetary Economics* 67: 62-77.

Wallace, Neil. 1981. "A Modigliani-Miller Theorem for Open-Market Operations." *American Economic Review* 71 (3): 267-74.

Weale, Martin, and Tomasz Wieladek. 2016. "What Are the Macroeconomic Effects of Asset Purchases?" *Journal of Monetary Economics* 79: 81-93.

Welch, Ivo, and Amit Goyal. 2008. "A Comprehensive Look at The Empirical Performance of Equity Premium Prediction." *Review of Financial Studies* 21 (4): 1455–508.

Werning, Ivan. 2012. "Managing a Liquidity Trap: Monetary and Fiscal Policy." http://economics.mit.edu/files/7558. Accessed on 2020-04-29.

Williams, John. 2016. "Discussion of 'Language after Liftoff: Fed Communication Away from the Zero Lower Bound'." Presentation at US Monetary Policy Forum, New York, New York, February 26.

Woodford, Michael. 2012. "Methods of Policy Accommodation at the Interest-Rate Lower Bound." In *The Changing Policy Landscape*, 185-288. Proceedings of the Federal Reserve Bank of Kansas City Economic Policy Symposium, Jackson Hole, WY, August 30 – September 1.

Wright, Jonathan H. 2012. "What Does Monetary Policy Do to Long-Term Interest Rates at the Zero Lower Bound?" *Economic Journal* 122 (564): F447-66.

Wu, Tao. 2014. "Unconventional Monetary Policy and Long-Term Interest Rates." International Monetary Fund Working Paper 14/189.

Wu, Jing Cynthia, and Fan Dora Xia. 2016. "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound." *Journal of Money, Credit and Banking* 48 (2-3): 253-91.

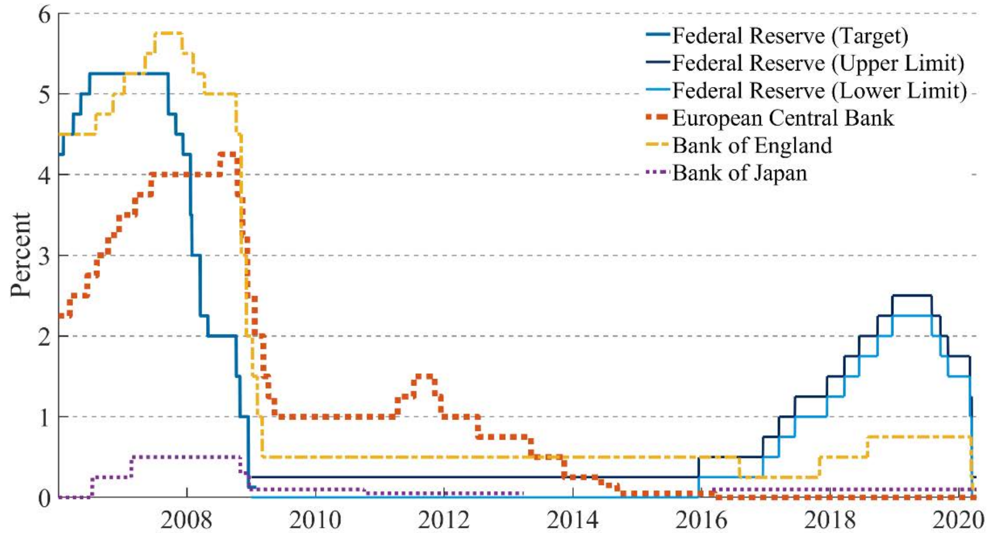
Wu, Jing Cynthia, and Fan Dora Xia. 2019. "Negative Interest Rate Policy and the Yield Curve." National Bureau of Economic Research Working Paper 25180.

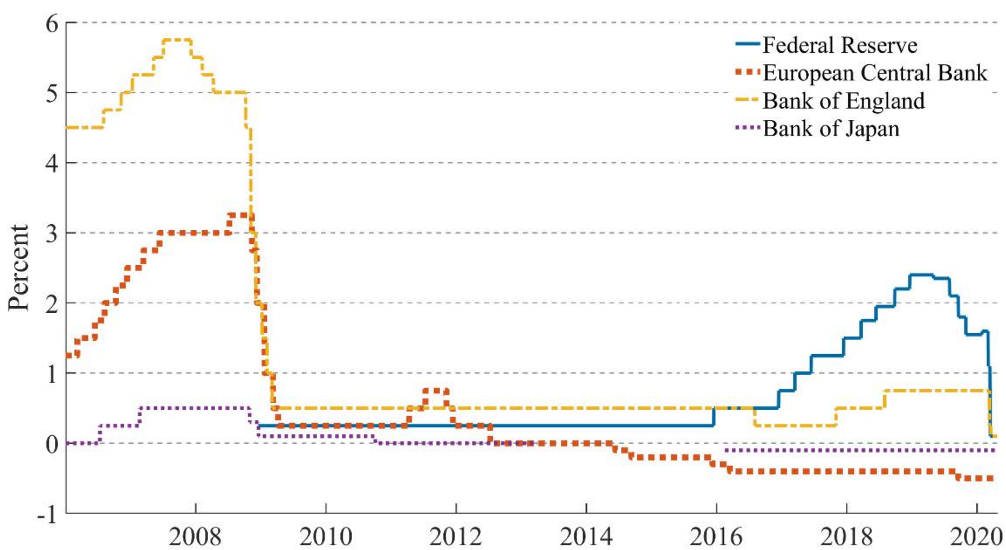
Wu, Jing Cynthia, and Ji Zhang. 2019a. "A Shadow Rate New Keynesian Model." *Journal of Economic Dynamics and Control* 107: 103728.

Wu, Jing Cynthia, and Ji Zhang. 2019b. "Global Effective Lower Bound and Unconventional Monetary Policy." *Journal of International Economics* 118: 200–16.

Yellen, Janet. 2012. "Janet Yellen in Her Own Words: An Exclusive Interview." Interview by Jim Tankersley. November 2012. https://www.washingtonpost.com/news/wonk/wp/2013/10/09/janet-yellen-in-her-own-words-an-exclusive-interview/

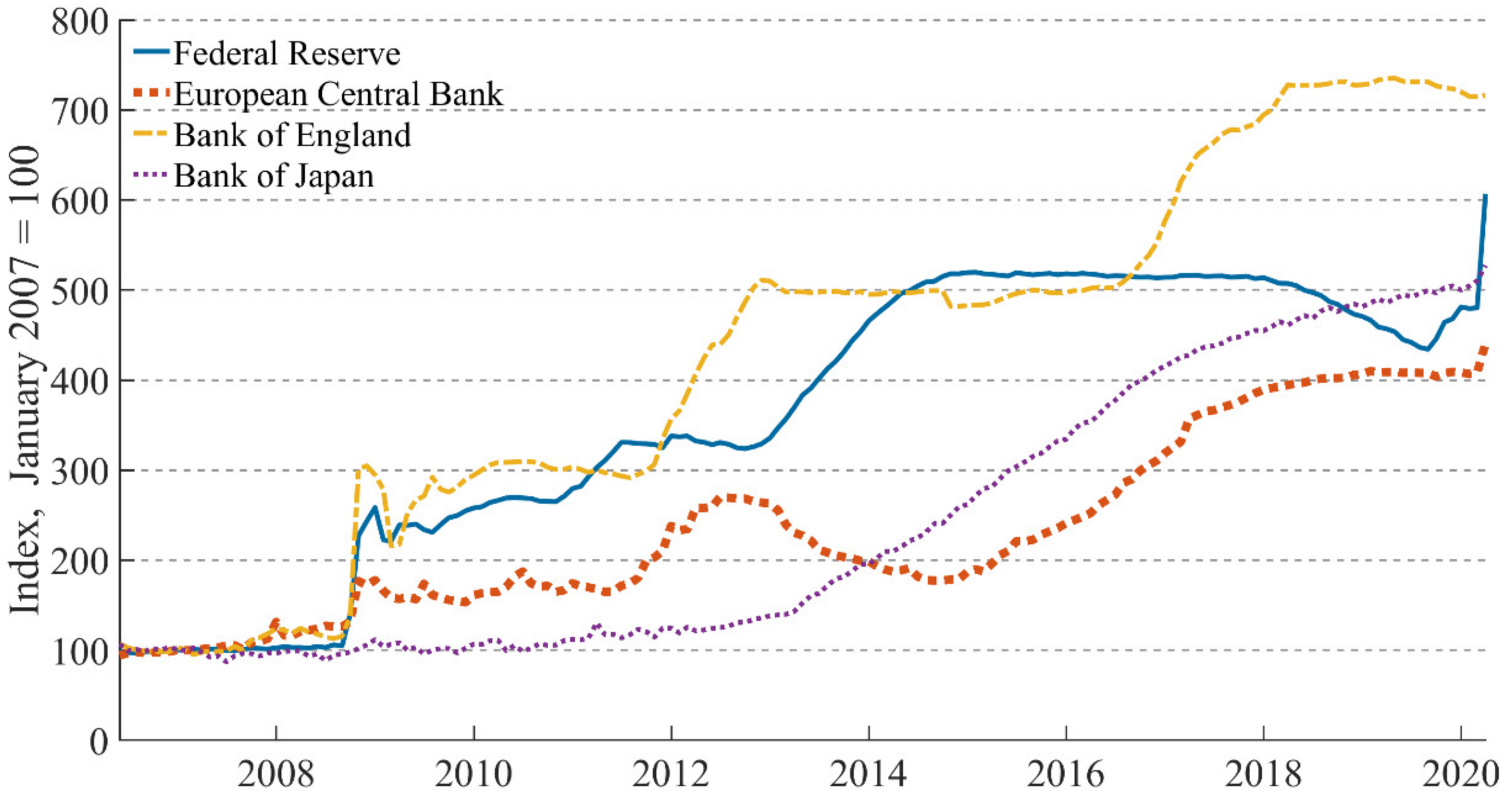
Figure 1: Major central bank policy and deposit rates: 2006-2020



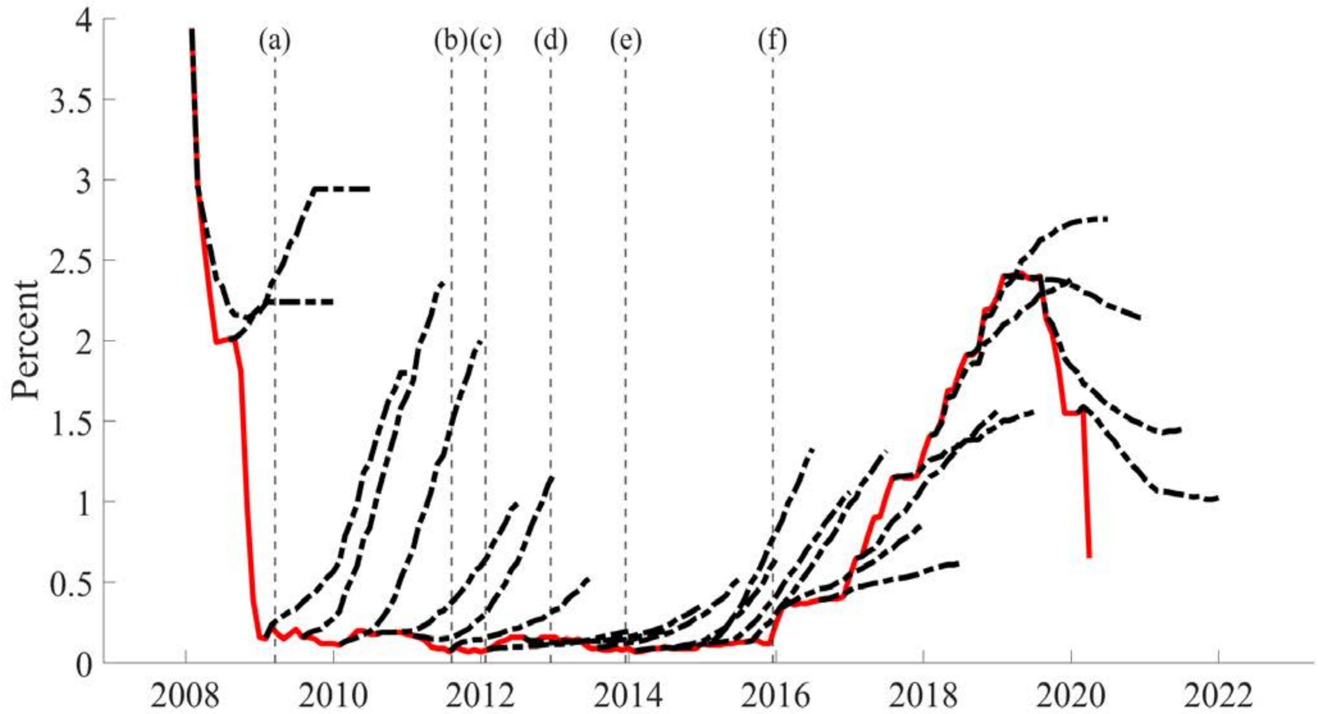

SOURCES: Bank of England, Bank of Japan, European Central Bank, Federal Reserve.
NOTE: Upper panel: The key policy rates for the BOE, Fed, ECB, and BOJ are, respectively, the Official Bank Rate, the Federal Funds Target Rate, the Main Refinancing Operations Rate, and the Uncollateralized Overnight Call Rate. Starting in December 2008, the Fed began targeting a federal funds range rather than a target rate. Between April 2013 and February 2016, the BOJ did not set a target for the uncollateralized overnight call rate. Starting in February 2016, the BOJ resumed targeting a short-term interest rate, for which we report the BOJ's basic balance rate, which is part of a tiered system of interest rates. See the January 2016 BOJ announcement for more information on the tiered system: https://www.boj.or.jp/en/announcements/release_2016/k160129a.pdf. The upper panel of Figure 1 is similar to Figure 3 in Neely and Karson (forthcoming).
Lower panel: 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 2: Assets holdings of major central banks: 2006-2020




SOURCES: Bank of England, Bank of Japan, European Central Bank, Federal Reserve.
NOTE: The figure shows asset holdings of the BOE, Fed, ECB, and BOJ between May 2006 and March 2020. Asset holdings are, respectively, normalized to equal 100 in January 2007. Figure 2 is similar to Figure 4A in Neely and Karson (forthcoming).

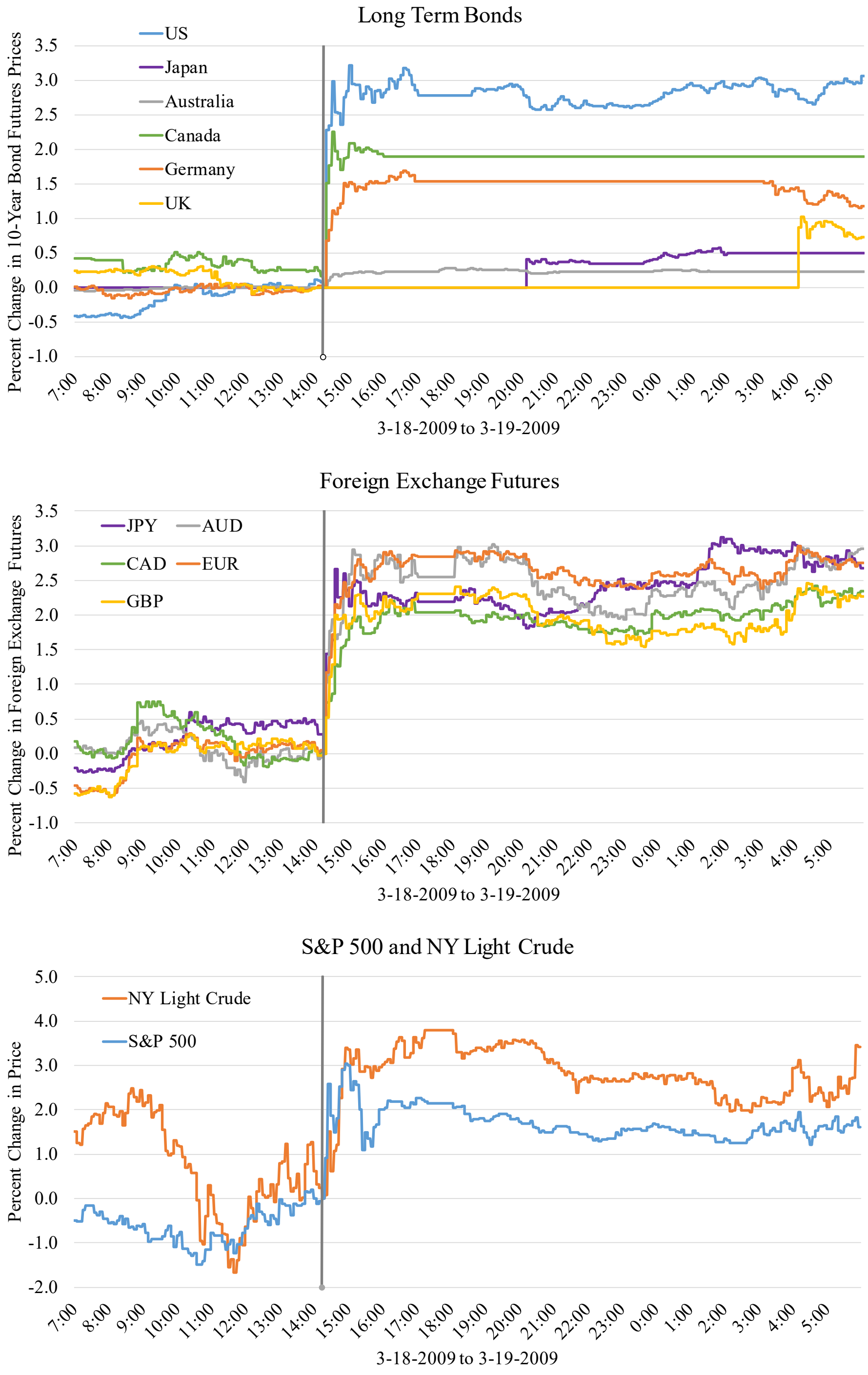
Figure 3: The federal funds rate and fed funds futures: 2008-2022




SOURCES: Federal Reserve, Bloomberg, DB Global Research.

NOTE: The red line is the effective federal funds rate, while the dashed black lines are short rates implied by futures prices. The dates for the vertical line are as follows: (a) 3/18/2009: Federal funds rate will remain exceptionally low “for an extended period.” (b) 8/9/2011: Federal funds rate will remain exceptionally low “at least through mid-2013.” (c) 1/25/2012: Federal funds rate will remain exceptionally low “at least through late 2014.” (d) 12/12/2012: Federal funds rate conditioned on unemployment and inflation. (e) 12/18/2013: Current target range maintained “well past the time” that unemployment falls to less than 6.5 percent. (f) 12/16/2015: The FOMC expects “only gradual increases” in the federal funds rate.

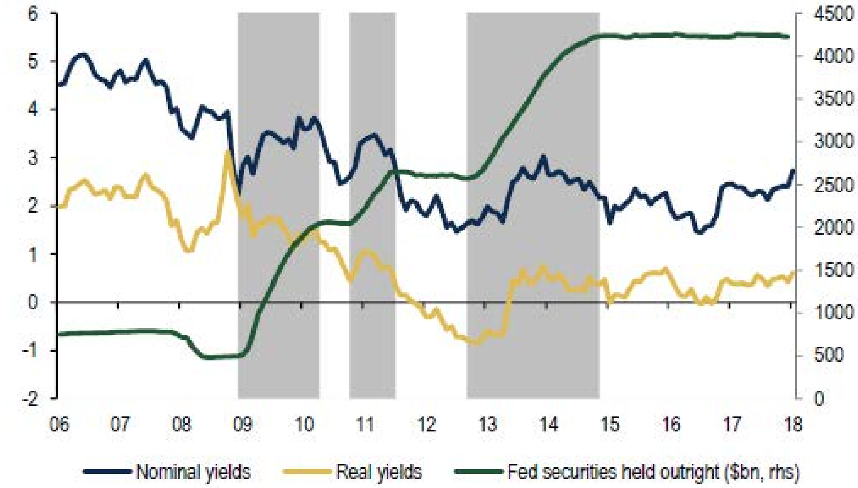
Figure 4: High-frequency nominal futures price movements on March 18, 2009




SOURCE: Tick Data.
NOTE: The figure shows the high-frequency movements of local currency international bond futures prices (top panel), exchange rate futures (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 times are in U.S. Eastern Time and the vertical line denotes 2:15 pm Eastern time. The figure is adapted from a figure in the appendix of Neely (2015).

Figure 5: U.S. bond yields during Fed asset purchases

**Exhibit 4.1.** Bond yields tended to rise during the implementation of QE1, 2 and 3



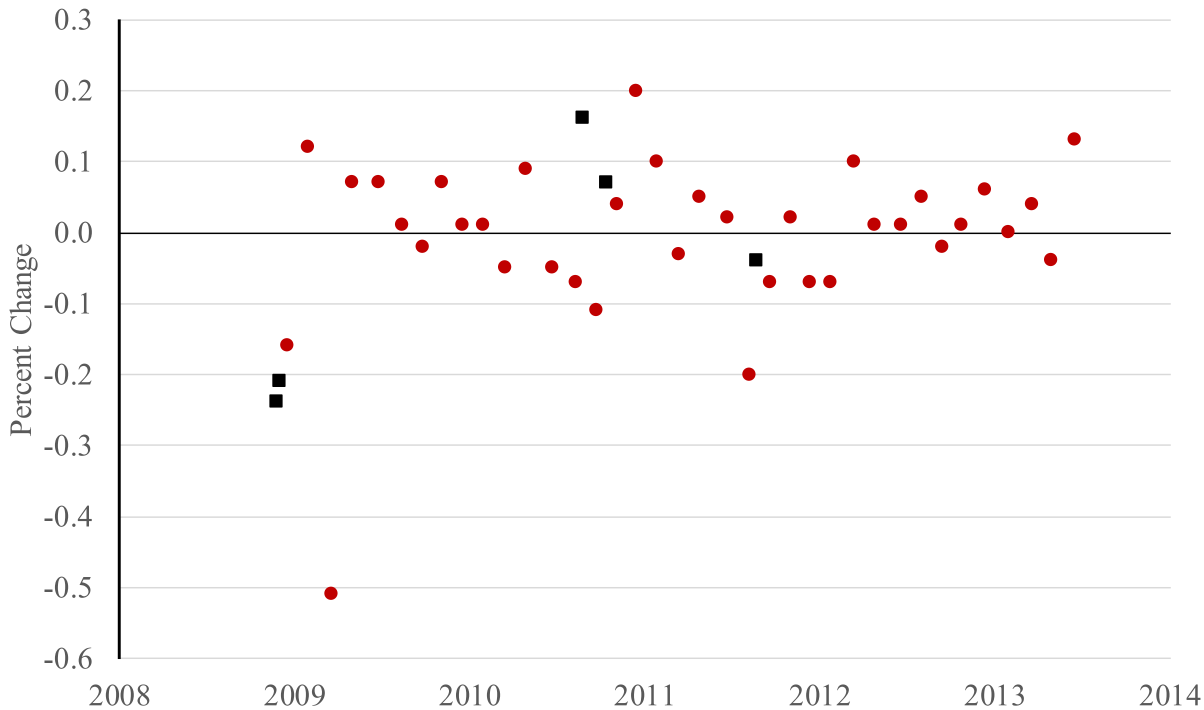

Notes to Exhibit 4.1. The shaded area in this and all subsequent charts shows the period of balance sheet expansion: Jan 2009 to Mar 2010 for QE1, Nov 2010 to June 2011 for QE2 and Oct 2012 to Oct 2014 for QE3. Many of the announcement effects should come before or at the start of the shaded areas.

**Exhibit 4.2.** Cumulative change in yields on all "Fed Days" ( meeting, minutes, chair speech)


Notes to Exhibit 4.2. The cumulative move is the sum of the actual change in yields on days of FOMC meetings, minutes and Chair speeches and with zero for non-Fed Days. The cumulative change in this and all subsequent charts is in b.p..

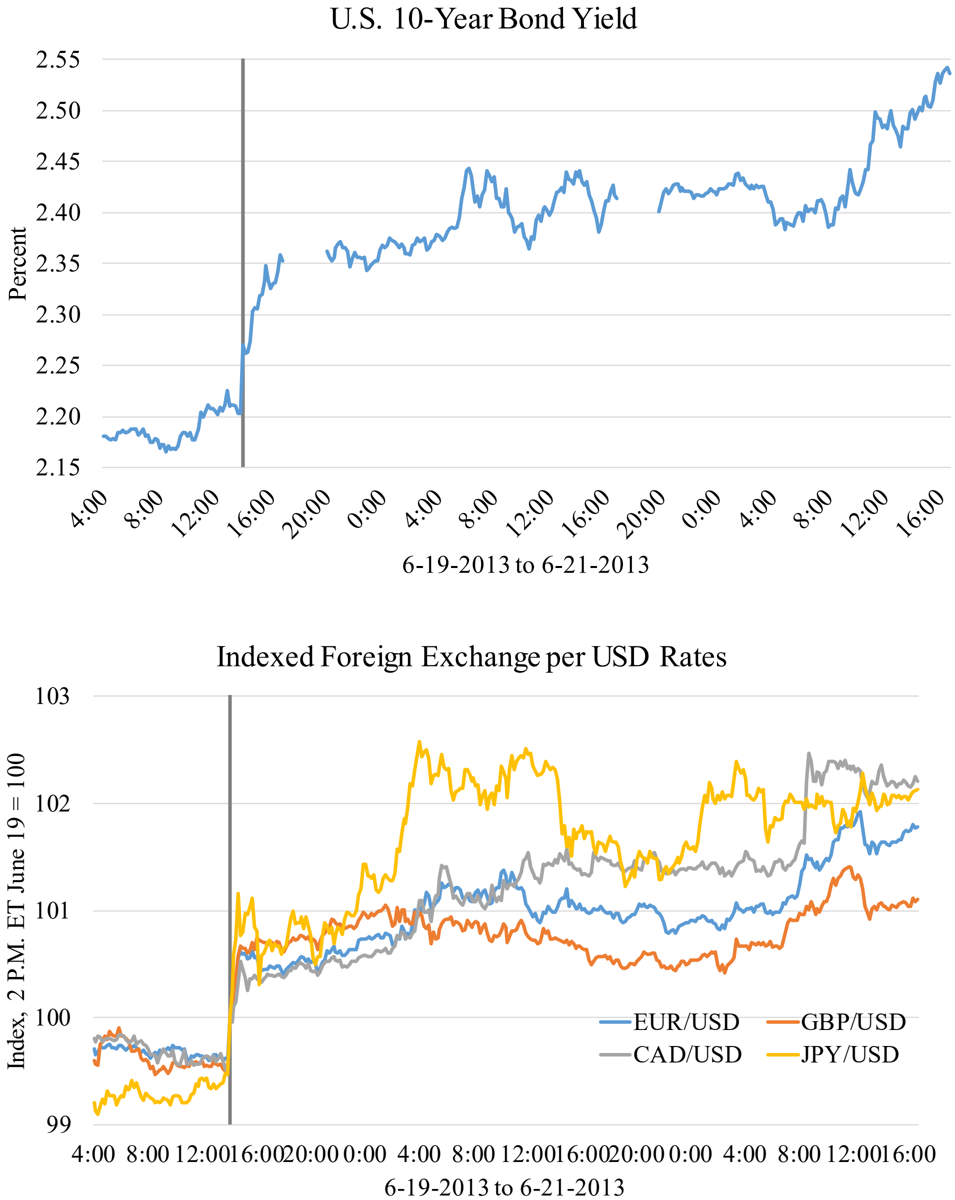
NOTE: The figures are excerpted from Greenlaw et al. (2018)

Figure 6: Daily 10-year Treasury yield changes around 42 unconventional monetary policy announcements




SOURCE: FRED.
NOTE: The figure illustrates daily changes in 10-year constant maturity U.S. Treasury yields on 42 days of monetary policy announcements (i.e., FOMC meetings, speeches, press releases) from 11/25/2008 to 7/31/2013. Red circles denote dates of FOMC meetings; black squares denote other events, such as press releases or speeches.

Figure 7: 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 vertical lines denote 2:15 pm Eastern Time, 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: The impact of QE1 events on yields

| Date | Event | Two-Year U.S. Treasury | Ten-Year U.S. Treasury | Ten-Year Agency | Agency MBS[b] | Ten-Year Term Premium | Ten-Year Swap | Baa Index |
|---|---|---|---|---|---|---|---|---|
| 11/25/2008[a] | Initial LSAP Announcement | -2 | -22 | -58 | -44 | -17 | -29 | -18 |
| 12/1/2008[a] | Chairman speech | -8 | -19 | -39 | -15 | -17 | -17 | -12 |
| 12/16/2008[a] | FOMC statement | -9 | -26 | -29 | -37 | -12 | -32 | -11 |
| 1/28/2009[a] | FOMC statement | 10 | 14 | 14 | 11 | 9 | 14 | 2 |
| 3/18/2009[a] | FOMC statement | -22 | -47 | -52 | -31 | -40 | -39 | -29 |
| 4/29/2009 | FOMC statement | 1 | -1 | -1 | 6 | 6 | 8 | -3 |
| 6/24/2009 | FOMC statement | 10 | 6 | 3 | 2 | 4 | 4 | 5 |
| 8/12/2009[a] | FOMC statement | -2 | 5 | 4 | 2 | 3 | 1 | 2 |
| 9/23/2009[a] | FOMC statement | 1 | -3 | -3 | -1 | -1 | -5 | -4 |
| 11/4/2009[a] | FOMC statement | -2 | 6 | 8 | 1 | 5 | 5 | 3 |
| 12/16/2009 | FOMC statement | -2 | 1 | 0 | -1 | 1 | 1 | -1 |
| 1/27/2010 | FOMC statement | 11 | 3 | 4 | 4 | 1 | 3 | 1 |
| 3/16/2010 | FOMC statement | -3 | -5 | -4 | -4 | -4 | -4 | -5 |
| 1/6/2009 | Minutes release | 0 | -4 | 3 | -17 | -1 | -9 | -14 |
| 2/18/2009 | Minutes release | 9 | 11 | 4 | 6 | 8 | 9 | 16 |
| 4/8/2009 | Minutes release | 2 | -4 | -7 | -9 | -4 | -6 | -6 |
| 5/20/2009 | Minutes release | -5 | -5 | -5 | -7 | -4 | -4 | -10 |
| 7/15/2009 | Minutes release | 7 | 13 | 16 | 16 | 10 | 16 | 7 |
| 9/2/2009 | Minutes release | -1 | -6 | -6 | -4 | -7 | -8 | -5 |
| 10/14/2009 | Minutes release | 1 | 7 | 10 | 3 | 7 | 7 | 8 |
| 11/24/2009 | Minutes release | 0 | -5 | -5 | -9 | -5 | -6 | -3 |
| 1/6/2010 | Minutes release | -2 | 6 | 5 | 4 | 6 | 7 | -1 |
| 2/17/2010 | Minutes release | 4 | 7 | 7 | 8 | 6 | 8 | 5 |
| Baseline event set | | -34 | -91 | -156 | -113 | -71 | -101 | -67 |
| Baseline set + all FOMC | | -1 | -55 | -134 | -114 | -47 | -75 | -72 |
| Cumulative change 11/24/08 to 3/31/2010 | | -19 | 50 | -75 | -95 | 30 | 28 | -489 |
| Std dev of daily changes: 11/24/08 to 3/31/10 | | 5 | 8 | 9 | 10 | 6 | 9 | 7 |

SOURCES: Bloomberg L.P.; Barclay's Capital; Board of Governors of the Federal Reserve System.
NOTE: This table is excerpted from Gagnon et al. (2011), where its title is "Table 1: Interest Rate Changes around Baseline and Extended Event Set Announcements." The changes in the table are in b.p..

[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.