Monetary policy transmission channels and policy instruments*

Carl E. Walsh†

May 2014

Abstract

The Federal Reserve has implemented policies during the past six years that rely on channels of transmission to the real economy that economic models have assumed to exist but seldom tested or on channels that were simply presumed not to exist. I discuss the board channels of monetary policy transmission that may allow forward guidance and balance sheet policies to affect the economy. The assumption that only real interest rates matters is key to many policy recommendations at the zero lower bound, so I provide some empirical evidence on this assumption. I discuss the role of inflation expectations as instruments, an anchor, or an automatic stabilizer. I then review evidence on balance sheet policies, first assessing which rates and/or spreads such policies should be affecting if the objective is to stimulate real activity. I conclude with some potential lessons for monetary policy.

1 Introduction

Policy experimentation can be very good for social science researchers, and the last several years have seen a host of experiments by major central banks. As a consequence, a huge literature has developed to assess these experiments. Understanding what has worked and what hasn’t offers lessons about whether new tools will be returned to the shelf to be reserved for the next crisis, or whether they will become part of the standard instruments central banks employ in normal times.

†University of California, Santa Cruz, email: walshe@ucsc.edu.
The list of potential channels through which old and new monetary policy tools affect the economy includes ones operating primarily through price effects on asset, yields, collateral values, and exchange rates, and ones operating through quantity effects on reserves, relative asset supplies, capital flows, credit availability, and net worth. Modern macro models emphasize the first set of channels. When the primary instrument of monetary policy is a short-term interest rate, changes in this rate, or in its expected future path, affects returns on other assets through arbitrage activity by investors; changes in interest rates alter the intertemporal price of output, leading to changes in aggregate demand for consumption and investment goods; exchange rate movements cause substitution effects that alter the demand for domestic production; and asset prices, through wealth effects, further affect aggregate spending. These traditional channels are viewed as primarily affecting aggregate demand, with any effects on aggregate supply being either small or temporary so that monetary policy is ultimately neutral with respect to its effects on the real economy.

Quantity channels, as opposed to price channels, were topics of active academic debate during the 1960s and 1970s. Assets, both real and financial, were viewed as imperfect substitutes, so changes in the relative stocks of these assets resulting from open market operations would force adjustments in yields. This view was often associated with Tobin, as he set out a general framework in which asset demand functions depended upon vectors of returns and equilibrium required these returns adjust to equate demands to the stocks of each asset (Tobin (1969), see also Tobin and Brainard 1963). This view of the transmission process faded from the literature during the 1980s and had remained largely neglected until the recent financial crisis, when balance sheet policies by the Federal Reserve, the Bank of England, and the Bank of Japan have, at the zero lower bound, again become active policy instruments.¹

A central bank’s has, broadly speaking, two instruments: forward guidance and balance sheet policies. Forward guidance involves attempts to affect expectations of the future path of real interest rates and includes “normal” adjustments of the central bank’s policy interest rate \(i_t\), as such adjustments are likely to have significant effects on the economy only to the extent they are perceived to signal a change in the future path of

---

¹An earlier exception is Andrés et al. (2004) which incorporates some of Tobin’s ideas into a DSGE model. As Bauer and Rudebusch (2013) note, “The portfolio balance channel, which emphasizes the role of quantities of securities in asset pricing, runs counter to at least the past half century of mainstream frictionless finance theory.” (p. 7)
real interest rates. Balance sheet policies, incorporating both the size and composition of assets and liabilities, may also provide signals about the future path of real interest rates and therefore constitute a means of implementing forward guidance, but such policies may also have independent effects on asset prices and yields for a given future path of the policy rate.

Forward guidance aims to affect future real interest rates. Given the central role real interest rates play in discussions of the effects of monetary policy, section 2 investigates whether nominal interest rates and expected inflation have equal but opposite effects on the economy. Overall, the evidence suggests nominal rates and inflation expectations have effects that differ by more than just their sign.

At the zero lower bound, theory says central banks should promise higher future inflation to stimulate current economic activity. In practice, central banks have seemed more concerned with ensuring inflation expectations remain anchored than with using them as instruments to achieve policy objectives. In section 3, I discuss the role inflation expectations can play as an anchor, an instrument, or as an automatic stabilizer.

Section 4 turns to balance sheet policies. I show how pricing “wedges” are important for balance sheet policies to matter. The empirical literature on QE policies has focused predominately on their effects on financial markets rather than on whether they have been effective in stimulating economic activity. I review the evidence on how interest rates and spreads have been affected, but I also assess the impact of rates and spreads on real economic activity to determine which rates and spreads QE policies should be designed to influence. In sections 5, I briefly discuss the effects of monetary policy that operate through aggregate supply channels. Section 6 summarizes the implications for monetary policy.

2 Nominal rates, expected inflation, and real rates

Mainstream models assume monetary policy affects employment and output through channels that can be summarized in terms of a real interest rate gap – the gap between the real rate of interest and some benchmark level of the real interest rate, often that associated with the economy’s equilibrium in the absence of nominal rigidities. This view of the transmission mechanism is exemplified by the new Keynesian framework. In its most basic form, this model links current aggregate spending to expected future real income (the wealth channel) and the expected short-term riskfree real interest rate which,
in turn, is represented by the central bank’s policy instrument minus expected inflation. These links are reflected in the intertemporal first order condition that characterizes optimal consumption choice. When log linearized around the economy’s equilibrium in the absence of the nominal rigidities, this condition can be represented as

\[ c_t = E_t c_{t+1} - \sigma (r_t - r^n_t), \]  

where \( c_t \) is consumption, \( r_t \equiv i_t - E_t \pi_{t+1} \) is the real interest rate, \( i_t \) is the nominal rate, \( \pi_t \) is the inflation rate and \( r^n_t \) is the equilibrium real interest rate in the absence of nominal rigidities and is assumed to be independent of monetary policy. Variations in the real interest rate, affect spending, and variations in aggregate demand lead to changes in output as nominal rigidities prevent prices or wages (or both) from immediately adjusting.

Solving (1) forward under the assumption that the economy converges to its steady state equilibrium (so \( c_{t+T} \rightarrow 0 \) as \( T \rightarrow \infty \)),

\[ c_t = -\sigma E_t \sum_{i=0}^{\infty} (r_{t+i} - r^n_{t+i}) = -\sigma E_t \sum_{i=0}^{\infty} (i_{t+i} - \pi_{t+1+i} - r^n_{t+i}). \]  

Equation (2) implies that it is the current and future expected path of the real interest rate relative to \( r^n \) that matters. Hence, monetary policy is more effective if it can affect future expectations of the real interest rate gap. Even a long period during which the nominal interest rate is anticipated to be at zero, for example, need not diminish significantly the central bank’s ability to affect current spending if it is able to affect either expectations of future inflation while \( i \) is at zero or of the future real rate once the nominal rate has been raised above zero.

If (2) is correct, positive innovations to expected inflation should have the same effects as negative innovations to the nominal interest rate. Thus, if the nominal rate is at zero, higher expected future inflation is expansionary because it reduces real interest rates. Surprisingly, the hypothesis that only real rates matter is rarely tested. To examine this hypothesis, the next three subsections provide evidence on the effects of shocks to the nominal interest rate and inflation expectations from a VAR, estimate a DSGE model in which nominal rates and expected inflation are not restricted to enter only in the form

\[ \text{As many have observed, Euler conditions such as (1) are among the least empirically supported relationships in economics. Of course, without further restrictions on } r^n_t, \text{ (1) always holds true trivially.} \]

\[ \text{An exception is Wilcox (1990). See also the recent work of Wieland (2013).} \]
of the real interest rate, and estimate a backward-looking model of the economy.

2.1 VAR evidence

Consider a VAR system of the form

$$Z_t = A(L)Z_{t-1} + BX_t + e_t,$$

where $Z_t = [x_t \, \pi_t \, i_t \, \pi^e_t \, q_t]$ consists of five variables: $x$ is either GDP or one of its components, $\pi$ is the quarterly inflation rate measured by the GDP deflator (expressed at annual rates), $i$ is the nominal interest rate on one-year Treasury securities (constant maturity), $\pi^e$ is the one-year ahead expected inflation rate of the GDP deflator from the Survey of Professional Forecasters, and $q$ is a log index of commodity prices. The values taken by the variable $x$ are GDP, consumption, investment, durables consumption, non-durables consumption, services consumption, residential investment, and non-residential investment (each expressed in log per capita real terms). $X_t$ consists of a constant, time, and time squared. The data are quarterly and the estimation period is 1970:2 - 2007:4. The start date is dictated by the inflation expectations data and the end date is chosen to end the sample before the onset of the global financial crisis. A lag length of four is employed.\(^4\)

Figure 1 shows, for real GDP, consumption, investment, exports and imports, the effects of a 25 basis point innovation to the one-year nominal interest rate (left column) and to the survey-based measure of expected inflation (right column), together with 90 percent confidence intervals. The top left row shows the effects on (log) real GDP. The positive innovation to the nominal interest rate leads to a significant decline in real GDP with the peak effect occurring after seven quarters. An innovation to expected inflation raises real GDP over the first five quarters after the shock, though the responses are not statistically different from zero. Thus, the effects of the nominal rate and expected inflation are of opposite sign, as suggested by theory, but their temporal impacts look quite different.

A similar picture is seen in the responses of log real consumption (row two) and real investment (row three). In both cases, the nominal interest rate shock generates a pattern that is similar to the response of GDP, while expected inflation has no effect.\(^5\)

\(^4\)Basic on the AIC a lag length of 3 was indicated but could not be rejected relative to the choice of 4.
Figure 1: Impulse responses of GDP components to the nominal rate (left column) and expected inflation (right column). VAR described in text. Dashed lines are 90% confidence intervals.

The responses of exports and imports to innovations to the nominal rate and to expected inflation are similar, but the responses are not statistically different from zero.\(^5\)

Consumption and investment are disaggregated into durables, nondurables and services for consumption and residential and nonresidential for investment in figure 2. Each panel shows the impulse response of an expenditure category to the nominal interest rate in blue and to expected inflation in red. The first row replicates rows two and three of figure 1. Subsequent rows show disaggregate components of consumption (left column) and investment (right column). In general, the effects of expected inflation are insignificant regardless of which component of GDP is involved. The one exception is evidence

\(^5\)In any case, these impulse response functions are inconsistent with the basic Euler condition given by (1). If the consumption forecast error is defined as \(\phi_{t+1} \equiv c_{t+1} - E_t c_{t+1} \), (1) can be written as

\[
c_{t+1} - c_t = \sigma (i_t - E_t \pi_{t+1} - r_t) + \phi_{t+1}
\]

so that a rise in the nominal rate should generate a rise in future consumption relative to current consumption, a pattern the opposite of what is observed in 1 in which an innovation to the nominal rate forecasts a future fall in consumption. See Fuhrer and Rudebusch (2004) for empirical evidence on the role of expected future output in empirical specifications of the Euler equation.
Figure 2: Responses of components of consumption (left column) and investment (right column) to the nominal interest rate (blue) and expected inflation (red). VAR described in text.

of a negative effect on consumption of services 10-15 quarters after a positive shock to expected inflation. The sign of this effect is the opposite of that predicted if only the real interest rate mattered. For investment, a positive nominal interest rate shock has a statistically significant negative effect on total investment arising from its effect on residential investment. Shocks to expected inflation do not have statistically significant effects on any of the investment aggregates.

Figures 1 and 2 were based on ordering \( \pi^e \) before \( i \). Thus, common contemporaneous correlations between the two are attributed to expected inflation responding to movements in the nominal interest rate. If the Federal Reserve has responded to expected inflation, as suggested by a simple Taylor rule based on expected inflation, then \( \pi^e \) should be ordered first. And in this case, an innovation to expected inflation should have a contractionary, not an expansionary, impact on output. To see why, suppose the policy rule takes the form

\[
i_t = r^n_t + \phi E_t \pi_{t+1} + e_t; \quad \phi > 1.
\]
Figure 3: Impulse responses of GDP components to the nominal rate (left column) and expected inflation (right column) when expected inflation is ordered before the nominal interest rate.

Substituting this into (1) yields

\[ c_t = \mathbb{E}_t c_{t+1} - \sigma (\phi - 1) \mathbb{E}_t \pi_{t+1}, \]

with \((\phi - 1) > 0\). Figure 3 reports impulse responses when expected inflation is ordered before the nominal interest rate. As is apparent from a comparison with figure 1, results are little changed. Again, innovations to expected inflation have effects on aggregate expenditures that are not statistically different from zero.

Survey measures of expected inflation may be contaminated with measurement error, in which case it could be that the innovations to the expectations variable are many measurement errors. If so, we would not expect shocks to the survey measure to have effects on real interest rates or the economy. This interpretation would also imply that shocks to the expectations measure would have no effect on actual inflation. Figure 4 shows the responses of real GDP (repeated from figure 1) and actual inflation to an expected
inflation shock. The response of actual inflation is positive and statistically significant, suggesting that innovations to the survey measure are, at least in part, capturing more than just measurement error.\textsuperscript{6}

One reason responses to expected inflation may be statistically insignificant is that over the sample period, expectations have been quite stable, particularly over the period since 2000. This stability is illustrated in Figure 5, which shows the constant maturity 1-year and 10-year Treasury rates and the corresponding 1-year and 10-year inflation expectations from the Survey of Professional Forecasters. Particularly for the 10 year horizon, inflation expectations appear to have been extremely well anchored well before the Fed’s adoption of a 2\% target in 2011. Consequently, movements in the nominal 10-year rate are movements in the real interest rate. This is certainly also true for the 1-year rate until 2010. With the 1-year rate close to zero since then, movements in the real 1-year rate can, by construction, only reflect movements in expected inflation. However, as figure 6 shows, the ex-ante real 1-year rate has been very stable

\textsuperscript{6}This would be consistent with the Fed responding to raise nominal interest rates in response to a rise in expected inflation so that the output gap is unaffected but actual inflation does rise.
Figure 5: One-year and ten-year Treasury rates and SPF measures of expected inflation.

Figure 6: Nominal 1-year and 10-year Treasury rates and ex-post real rates based on SPF inflation expectations.
2.2 A DSGE model

A VAR provides some evidence on the relationships between nominal rate, expected inflation, and macro variables, but it does not exploit restrictions on the data that might be derived from an underlying structural model. Of course, structural models may impose restrictions that are false and so fail to accurately characterize the data. DSGE models of the type commonly developed by central banks assume nominal interest rates and expected inflation affect aggregate spending only in so far as each affects real interest rates. This restriction is not, to my knowledge, ever tested. These models also impose the assumption of rational expectations. Thus, rather than employ something such as a survey measure of expectations, expectations are treated as an unobservable whose behavior is restricted to be consistent with the true equilibrium processes implied by the model.

In this section, I report the results of reestimating a DSGE model due to Iacoviello and Neri (2010) when the assumption that $i_t$ and $E_t \pi_{t+1}$ enter behavioral equations only in the form $i_t - E_t \pi_{t+1}$ is relaxed. While there are many modern DSGE models one could choose from, the Iacoviello and Neri model is a relevant one to examine as it includes housing and also does not impose the restriction of a representative household. I modify their model to allow the nominal interest rate and expected inflation to enter in the form $i_t - (1 + \gamma_0) E_t \pi_{t+1}$, where $\gamma_0$ is an unknown parameter to be estimated. I assume a normal prior for $\gamma_0$ with mean equal to zero and a standard deviation of 1.0. Estimation results are reported in the first row of Table 1. The null hypothesis that $\gamma_0 = 0$ cannot be rejected, implying that it is in the form of the real interest rate that $i$ and $E_t \pi_{t+1}$ matter.

Because the Iacoviello and Neri model distinguishes between patient and impatient households, I also estimate the model when the effects of expected inflation are allowed to differ between the two household types. I let the real interest rate variable in the equations describing patient households by given by $i_t - (1 + \gamma_1) E_t \pi_{t+1}$. For impatient households, the variable is defined as $i_t - (1 + \gamma_2) E_t \pi_{t+1}$. Results for the estimates of $\gamma_1$ and $\gamma_2$ are given in the last two rows of Table 1. Interestingly, the parameter estimate

---

7I employ the programs and data available with the published version of Iacoviello and Neri (2010).
8Estimates of only two of the models other parameters (the standard error of the persistent shock to deviations of inflation from steady state and the growth rate of technology in the non-housing investment
of $\gamma_1$, like that of $\gamma_0$, is not statistically different from zero. However, the estimate of $\gamma_2$ differs from zero at the 10% level. In the Iacoviello and Neri model, patient households are unconstrained and therefore correspond to the standard representative household in models with homogeneous households and no financial frictions. The behavior of these households does seem to depend on the nominal interest rate and expected inflation only in the form of the real interest rate.

For constrained households, however, the situation appears to be different. For these households, the relevant inflation-adjusted interest rate is $i_t - 0.739E_t\pi_{t+1}$ so that equal increases in the nominal rate and expected inflation results in an increase in the effective real interest rate for these households. Expressed alternatively, a rise in expected inflation is only about three-fourths as effective as a cut in the nominal interest rate in stimulating spending by these households. This could reflect that borrowing constraints faced by some households may be affected by measures of ability to pay such as interest payments as a fraction of income; equal increases in expected inflation and the nominal interest rate, in this case, can tighten borrowing restrictions and force a reduction in spending.

While the estimates provide some evidence that one may not wish to force the nominal rate and expected inflation to enter only in the form of the real interest rate, the impulse response functions for the version that allows differences across household types differed little from those obtained in the original (restricted) Iacoviello and Neri model, suggesting that perhaps the standard restrictions are not too critical.

2.3 A backward-looking model: Rudebusch and Svensson (1999)

Modern DSGE models overwhelmingly are built on theoretical foundations that emphasize forward-looking behavior. In contrast, Rudebusch and Svensson (1999), in an early model estimated on U.S. data and used to evaluate monetary policy rules, specified and estimated a two-equation backward-looking model for output and inflation. While models that lack any forward-looking aspects are inconsistent with theory, there are three reasons for re-examining what a model like the Rudebusch-Svensson one can tell us about the separate effects of nominal rates and expected inflation. First, the model provides a very parsimonious fit to the time series data. Second, a backward-looking model may be more in accord with policy makers’ view of the economy. For example, Taylor’s original intu-
ition for the Taylor Principle is, as emphasized by Cochrane (2011), more consistent with a backward-looking model than a forward-looking model. Perhaps most importantly, the results of Levin and Williams (2003), and others suggest that evaluating policy rules in backward-looking models provides an important check for robustness.\(^9\)

The Rudebusch and Svensson (1999) model takes the form

\[
\pi_{t+1} = a_1 \pi_t + a_2 \pi_{t-1} + a_3 \pi_{t-2} + a_4 y_t + \varepsilon_{t+1}
\]

(3)

\[
y_{t+1} = b_1 y_t + b_2 y_{t-1} + b_3 (i_t - \bar{\pi}_t) + \eta_{t+1}
\]

(4)

where \(\pi_t = 400 \times (\ln p_t - \ln p_{t-1})\), \(p_t\) is the GDP chain-weighted price index, \(\bar{\pi}_t = (1/4) \sum_{i=0}^{3} \pi_{t-i}\), \(\bar{i}_t = (1/4) \sum_{i=0}^{3} i_{t-i}\), \(i\) is the federal funds rate. Equation (4) is the relevant one for investigating the role of the inflation adjusted nominal interest rate. Rudebusch and Svensson measure the output gap as log real GDP minus an estimated quadratic trend. I employ log real GDP relative to the log estimate of potential GDP from the Congressional Budget Office, and denote this by \(y_{cbo}\).\(^{10}\) Results are similar regardless of which of the two output gaps is used, so those from using the quadratic detrended output gap measure and results from re-estimating (3) are reported in the Appendix.

Columns 1, 3, and 5 of Table 2 report estimates for the basic Rudebusch-Svensson equation for their sample, 1961:1-1996:2, the sample extended to 2007:4, and the sample through 2013:4. For the longer samples, the estimated elasticity of the output gap with respect to \(i - \bar{\pi}\) is lower than found by Rudebusch and Svensson. The sample ending in 2013:4 includes the period since December 2008 during which the federal funds rate has been effectively at zero, but the model itself implies that it is only \(i_t - \bar{\pi}_t\) that matters and this variable has not been constant. However, the estimated coefficient on the ex-post real interest rate is lower by about one half when the Great Recession and slow recovery period is included.

Columns 2, 4 and 6 relax the assumption that \(i\) and \(\pi\) enter with coefficients that are equal but of opposite sign. For all sample periods, the estimated coefficients on the nominal interest rate are broadly similar to the coefficient on the real interest rate measure. In contrast, the coefficient on the inflation variable is never statistically significant.

---

\(^{9}\)For example, Walsh (2003).

\(^{10}\)Following Rudebusch and Svensson, means are subtracted from each variable so that no constants appear in either (3) or (4). Means and detrended log GDP are recalculated for each sample period used in the estimation.
Theory implies the coefficient should be positive, but the point estimates are negative in 5 of 6 cases, and zero to two digits in the 6th. The coefficient restriction is decisively rejected in all cases. There is no evidence here to support the hypothesis that it is the nominal interest rate adjusted for inflation that matters.

Rudebusch and Svensson employed a moving average of past inflation to proxy for expected inflation. As an alternative, I use the one-year ahead inflation expectations for the GDP deflator from the Survey of Professional Forecasters. This series is available beginning in 1970:2. Results for $y_t$ are reported in Table 3. Expected inflation has the wrong (though statistically insignificant sign) in 5 of the 6 specifications. In three of these six cases the null hypothesis that the nominal rate and expected inflation enter with equal but opposite signs could be rejected, but in two of these case (for the 1970:2-2013:4 sample), it was because the coefficients on each variable were essentially zero. For the 1970:2-2007:4 sample, expected inflation has a negative coefficient, but it is statistically insignificant.\textsuperscript{11}

It is interesting to compare the impulse responses of output and inflation to a monetary policy shock using the point estimates of the coefficients with the nominal rate and expected inflation are allowed to appear separately. To calculate the impulse responses, I close the model by estimating a simple Taylor rule over the 1960:1-2007:4 period using the CBO measure of the output gap.\textsuperscript{12} Figure 7 shows the impact of an innovation to the expected inflation measure in the Rudebusch-Svensson model using the estimated parameters obtained in their original specification, in which $i$ and $\bar{\pi}$ are constrained to enter in the form $i - \bar{\pi}$, and for the unconstrained parameter estimates from column 4 of Table 2. The contrasting impulse responses are essentially mirror images of each other. A rise in expected inflation (admittedly proxied by an average of lagged inflation) is contractionary, the opposite of the effect implied by standard models. Figure 8 shows the impact of an increase in expected inflation when the nominal rate is held at zero. Comparing this figure to 7 shows, not surprisingly, that the decline in output in response to a rise in expected inflation is more pronounced and the economy takes longer to recovery when

\begin{itemize}
    \item Expected inflation does have a positive coefficient using detrended GDP to measure the output gap, as predicted by theory, but the point estimate of the coefficient is only half the size in absolute value of the coefficient on the nominal rate (0.05 versus −0.10). Note that this difference is in the same direction as the finding for impatient households in the model of Iacoviello and Neri (2010).
    \item This yields $i_{t+1} = 0.953 \times i_t + (1 - 0.953) \times [0.518 \times \pi_t + 1.354 \times y_t]$.
\end{itemize}
IRF to an expected inflation shock: updated parameters
Real rate restriction imposed
Separate est. coeff. for $i$ and $\pi^e$

Figure 7: Response to an expected inflation shock. Solid line based on the restricted model; dashed lines on the unrestricted model.

the nominal rate cannot be cut to offset the contractionary impact of the rise in expected inflation.

2.4 Why might nominal rates and expected inflation have differential effects?

There are several reasons expected inflation and nominal interest rates may have effects that do not operate through the real interest rate. First, theory would suggest it is the after tax real rate that matters, and most tax systems are not fully indexed for inflation. If the tax system is not indexed, the after-tax real return will be

$$r_{t+1}^{after} \approx (1 - \tau) i_t - \pi^e_{t+1} = (1 - \tau) \left[ i_t - \frac{1}{1 - \tau} \pi^e_{t+1} \right],$$

where $\tau$ is the marginal tax rate. Note that in this case, however, the coefficient on $\pi^e$ would be greater than the coefficient on the nominal interest rate, which is not consistent with the evidence of the previous section. Second, in the U.S., many households have
Figure 8: Response to an expected inflation shock in the unrestricted model when the nominal interest rate is held at zero.

fixed-rate, long-term mortgage debt that involve constant nominal monthly payments over the life of the mortgage. A rise in expected inflation that is fully incorporated into the nominal loan rate has the effect of shifting forward the time profile of real payments. An increase in expected inflation, holding the real interest rate fixed, would decrease the demand for housing by households facing repayment constraints related to their current income. This effect is consistent with the DSGE estimates. Third, if debt is denominated in nominal terms, inflation can generate Fisher debt-deflation effects. A rise in inflation would be expansionary effect. This channel relies on distributional effects as the fall in real liabilities for debtors is offset by a fall in the real assets of credits (see Eggertsson and Krugman (2012), Wieland (2013), Carlstrom et al. (2014), Gorodnichenko et al. (2012), and Gornemann et al. (2013). Fourth, if firms must finance inventories or wage payments, the nominal interest rate may directly affect employment and production decisions through a cost channel as in Chari, Christiano, and Eichenbaum (1995) or Ravenna.

13 For example, the real value of the first year payment on a $300,000 fixed rate 30-year mortgage with a real interest rate of 3.5% is $1,706 per month if inflation is 2% versus $2,098 at a 4% inflation rate. If borrowing limits are linked to measures of repayment relative to income, at 4% inflation, the annual first year payment on a $244,000 mortgage is about the same as that on a $300,000 mortgage with 2% inflation.
and Walsh (2006). Similar effects occur in models in which households use non-interest bearing nominal assets to finance consumption; in this case, the nominal interest rate, not the real rate, acts like a tax on consumption. Fifth, individuals may suffer from money illusion. Early experimental work by Fehr and Tyran (2001) concluded that individuals did suffer from money illusions, and Yellen and Akerlof (2006) cite this evidence in their discussion of monetary non-neutrality. However, Petersen and Winn (2199) (forthcoming) show how the results of Fehr and Tyran were built into their experimental design. When the experimental design is corrected, Petersen and Winn (2199) find no evidence in support of money illusion. See also Kryvtsov and Petersen (2013). Finally, if inflation follows an AR(1) process with coefficient $\rho$, where $\pi$ is positive but less than one, then

$$i_t - E_t \pi_{t+1} = i_t - \rho \pi_t,$$

which would be consistent with finding smaller effect of inflation than the nominal interest rate. This could then account for the findings in the Rudebusch-Svensson model in which lagged inflation served as a proxy for expected inflation. However, similar empirical results were obtained using survey measures of expected inflation, and re-estimating the Iacoviello and Neri (2010) model, rational expectations were imposed.

2.5 Summary

Economic models assume it is the real interest rate that matters. At the zero lower bound, raising expected inflation is a perfect substitute for cutting nominal rates. The evidence suggests nominal interest rates and expected inflation do not affect the economy in equal but opposite ways. In the VAR estimates, shocks to expected inflation generally did not have significant effects on components of aggregate spending, components that were affected by nominal interest rate shocks.

Structural models impose the assumption that agents’ decisions depend on real interest rates. Relaxing this assumption in a modern DSGE model due to Iacoviello and Neri (2010) which allows for heterogeneity among households revealed some evidence that the model’s constrained households were affected differentially by changes in the nominal interest rate and expected inflation. This particular model still implies that efforts to raise expectations of future inflation would stimulate aggregate output when the nominal interest rate is at the zero lower bound, though such efforts are somewhat less effective than cutting the nominal interest rate would be in normal times.
Finally, the evidence from the backward-looking Rudebusch-Svensson model provided no support for the standard view that increases in inflation are expansionary for a given nominal interest rate. Given other evidence that policies designed to work well in a backward-looking model such as that of Rudebusch and Svensson are more robust to model misspecification, the lack of support this model gives to the hypothesis that higher expected inflation is expansionary raises questions about proposals to raise expected inflation at the zero lower bound.

3 Forward guidance

The real interest rate channel is central to discussions of forward guidance since even when the nominal policy rate is at zero, (2) still implies that policy can affect aggregate demand by influencing future expectations about inflation and the path of the policy rate. If the policy rate is currently at zero and is anticipated to remain there for $S$ periods, then (2) can be written as

$$c_t = \sigma E_t \left[ \sum_{i=0}^{S} \pi_{t+1+i} + \sum_{i=S+1}^{\infty} (\pi_{t+i} - \pi_{t+1+i}) + \sum_{i=0}^{\infty} r^n_{t+i} \right].$$

The central bank can stimulate aggregate spending 1) by providing information about the future state of the economy as summarized in the term $\sigma E_t \sum_{i=0}^{\infty} r^n_{t+i}$; 2) by causing an increase in expectations of future inflation during the period over which the nominal rate is kept at zero; 3) by creating expectations that the nominal rate will be kept at zero for longer (an increase in $S$), or 4) by reducing the private sector’s expectations about future real interest rates once the nominal rate is increased from zero. Not surprisingly, both academics and policy makers have viewed influencing expectations as a particularly critical policy instrument at the zero lower bound. The Bank of Japan, for example, was urged to raise expectations of inflation by many prominent economists, including Ben Bernanke, Lars Svensson and Paul Krugman.

Forward guidance involves statements about the future path of policy instruments designed to affect expectations of private sector agents in a manner that contributes towards achieving the central bank’s objectives. When a central bank has been acting in a systematic manner that is well understood by the public, there may be little to gain by making statements about the future path of policy instruments. Statements about
future policy itself, as opposed to information about the central bank’s outlook for the economy, would either lack informational content or risk the central bank’s credibility if the statements differed from what the public, based on past policy, expected the central bank to do in future circumstances. The difficulty of conveying information about how policy will be conducted in future situations that have not previously been encountered can be extreme, especially when, as is the case at the zero lower bound, there may be no direct and observable action the central bank can take now to reinforce it’s statements about what it will do in the future. In this case, statements risk being interpreted as conveying information about the central bank’s forecast of the economy. This situation, a case Campbell et al. (2012) label Delphic, need not arise only at the ZLB; cutting the policy rate sharply in face of a severe contractionary shock “may lead the public to revise downward their expectations about the state of the economy in the belief that the central bank must think the outlook is worse than previously thought. In this case, rather than promoting expectations of a future expansion, public expectations might deteriorate, worsening the contraction in economic activity.” (Walsh (2009) p. 254)

When the standard policy instrument is at zero, the challenge is to provide information about how the central bank will act in the future, what Campbell et al. (2012) call Odyssian guidance. The debates over forward guidance revolve around the ability of the central bank to affect expectations about future inflation and economic activity by creating beliefs (which must eventually be fulfilled) that monetary policy will not be tightened too soon when the economy strengthens. Statements about keeping rates low for expected periods may not convey information that is specific enough to move expectations in the way policy makers desire, while linking guidance to specific macroeconomic variables such as the unemployment rate can cause problems when there are forecast surprises.\footnote{Such as was the case when the unemployment rate in the UK declined more rapidly than the Bank of England had anticipated.}

Despite these difficulties, there is evidence that the Fed’s forward guidance has been effective in lowering long-term Treasury rates. Raskin (2013) argues, based on options-based estimates of the distribution of interest rate forecasts, that the FOMC has been able to alter market expectations of the Fed’s future reaction function. As discussed below in section 4, Bauer and Rudebusch (2013) suggest that much of the effect of QE policies has actually been due to the forward guidance or signalling channel of these policies, and Krishnamurthy and Vissing-Jorgensen (2013) attribute a sizable fraction of...
the response to QE announcements to signally effects. Recently, Christiano et al. (2014) have examined the effect of the Fed’s forward guidance using a DSGE model that captures the behavior of the U.S. economy during the Great Recession. While their benchmark model represents policy by a Taylor rule subject to the zero lower bound, beginning in the third quarter of 2011 they incorporate market forecasts about how long the funds rate will remain at zero to capture the impact of Fed statements about the future path of the funds rate. They find that this forward guidance had a significant effect in raising real output relative to their baseline.

3.1 Inflation expectations: an anchor, an instrument, or an automatic stabilizer?

Forward guidance uses expectations as policy instruments. This is just one of three roles expectations might play: expectations may be an instrument, an anchor that limits destabilizing movements in future expectations, or as an automatic stabilizer.

3.1.1 Expectations as an instrument

Beginning with Krugman (1998), the recommendation for a central bank constrained by the ZLB has been to raise inflation expectations. In optimal commitment policies, future expectations are policy instruments. As stressed by Woodford (2012), forward guidance at the ZLB requires that policy makers commit to a path that involves lower nominal interest rates and a temporarily higher future rate of inflation than would be called for under a purely forward-looking policy. This type of forward guidance seeks to use expectations of future inflation as an additional policy instrument. By doing so, the fully optimal commitment policy is able, to a large degree, to mitigate the adverse effects of the negative shock that pushes the current policy rate to zero, as has been shown by Eggertsson and Woodford (2003), Nakov (2008), Adam and Billi (2006), and others.

However, optimal policy tells one how the central bank would wish private sector beliefs to evolve at the ZLB without providing an operational mechanism for achieving this when the central bank finds itself at the ZLB for the first time, since the bank cannot point to how it behaved in the past as a means of guiding future expectations.\footnote{The difficulties of steering expectations is illustrated by the experience of the Riksbank during 2009-2011 (see Svensson 2011, Woodford (2012)). Market expectations failed to match the Riksbank’s announced future path for the repo rate, in one case (April 2009), failing to match the announcement that a 50 basis point level of the repo rate would be maintained into 2011 and, in a second case, failing (correctly}
Promises to keep rates low beyond when they might normally be raised is subject to a time inconsistency problem – when the economy strengthens, the optimal policy is to ignore past commitments. In an interview with the *Financial Times* (3/3/2014), John Williams, President of the Federal Reserve Bank of San Francisco was reported as saying he expected the Fed to raise interest rates when the unemployment rate reached about 6 percent and while inflation was around 1.5 percent. “At that point if we don’t start to adjust monetary policy there’d be a risk of overshooting,” he is quoted as saying. “You don’t wait until you’re at full employment before you start to raise interest rates from zero.” But since inflation at 1.5 percent would still be below the Fed’s 2 percent target, and estimates of full employment generally associated it with an unemployment rate at or below 6 percent, the signal being conveyed does not appear to be consistent with the prescription to allow an overshooting of the inflation target as a means of stimulating the economy now.

Levin et al. (2010) examine optimal commitment policy in a new Keynesian model and find that “Although forward guidance is effective in offsetting natural rate shocks of moderate size and persistence, we find that the macroeconomic outcomes are much less appealing for larger and more persistent shocks, especially when the interest elasticity parameter is set to values widely used in the literature.” (p. 143)

3.1.2 Anchoring expectations

One of the successes of inflation targeting is that it has anchored inflation expectations. Early in the Great Recession, major central banks seemed united in their unwillingness to abandon the anchor. For example, in testimony before the House Committee on Financial Services in July 2009, six months after the federal funds rate had been cut essentially to zero, Federal Reserve Chairman Bernanke stressed that the Fed would prevent a rise in inflation as the economy recovered from the recession, stating “…it is important to assure the public and the markets that the extraordinary policy measures we have taken in response to the financial crisis and the recession can be withdrawn in a smooth and timely manner as needed, thereby avoiding the risk that policy stimulus could lead to a future rise in inflation.” As discussed in Walsh (2009), a promise to keep the policy interest rate at zero beyond when it would normally be raised as the economy

---

as it turned out) to believe the Riksbank’s projected path of future rate increases. Svensson (2011) offers a number of potential explanations, all of which are plausible but untestable.
recovers, while simultaneously also promising to avoid future increases in inflation, is an inconsistent policy, at least according to the rational expectations theoretical framework at the heart of policy models.

But can there be advantages to simply anchoring inflation expectations? Consider the following basic model characterized by the standard consumption Euler equation, a new Keynesian Phillips curve, and a Taylor rule describing monetary policy:

\[ x_t = E_t x_{t+1} - \sigma \left( i_t - \pi^e_{t+1} - r^n_t \right); \]  
\[ \pi_t - \pi^T = \beta \left( \pi^e_{t+1} - \pi^T \right) + \kappa x_t + u_t; \]  
\[ i_t = r^n + \pi^T + \phi_\pi \left( \pi_t - \pi^T \right) + \phi_x x_t. \]  

The central bank’s inflation target is \( \pi^T \). Rather than identifying inflation expectations as equal to model-consistent rational expectations, suppose

\[ \pi^e_{t+1} = (1 - \delta) E_t \pi_{t+1} + \delta \pi^T. \]  

The parameter \( \delta \) controls the degree to which expectations are anchored at the inflation target. If \( \delta = 1 \), \( \pi^e_{t+1} = \pi^T \), and inflation expectations are fully anchored. If \( \delta = 0 \), \( \pi^e_{t+1} = E_t \pi_{t+1} \) and expectations are equal to model-consistent, rational expectations. Further, suppose outcomes are evaluated based on a quadratic loss function given by

\[ L_t = \left( \frac{1}{2} \right) E_t \sum_{i=0}^{\infty} \beta^i \left[ (\pi_{t+i} - \pi^T)^2 + \lambda x_{t+i} \right]. \]

For calibration purposes, I set \( \beta = 0.99 \), \( r^n = \beta^{-1} - 1 = 0.0101 \), \( \pi^T = 0.005 \) (equal to a 2% inflation target expressed at annual rates), \( \sigma = 1 \), \( \kappa = 0.024 \), \( \phi_\pi = 1.5 \), and \( \phi_x = 0.5/4 \). The parameter \( \lambda \) is set at \( \kappa / [(1 + \eta \varepsilon) \varepsilon] \) where \( \varepsilon = 6 \) is the the price elasticity of demand facing individual firms and \( \eta = 1 \) is the inverse wage elasticity of labor supply. The standard deviation and autocorrelation coefficient for the markup shock \( u \) are taken to be 0.02 and 0.8 respectively. For the natural real interest rate process, I assume

\[ r^n_t = r^n + E_t z_{t+1} - z_t \]

which corresponds to log utility and quadratic disutility of labor hours, where \( z_t \) is an ag-
aggregate productivity shock with standard deviation 0.007 and autocorrelation coefficient 0.9.

Figure 9 plots the loss under optimal discretion as a function of $\delta$. Loss decreases with $\delta$, that is, the economy is more stable (as measured by $L_t$) the more anchored inflation expectations are at the central bank’s inflation target. Of course, the decrease in loss could be consistent with one of the target variables, either the output gap or inflation, becoming more volatile while the other becomes less so. Figure 10 shows the variances of the output gap and inflation (around the target) as a function of $\delta$; both become more stable when expectations are more firmly anchored. It is perhaps not surprising, therefore, that central banks have been reluctant to weigh anchor and steer expectations in the manner theoretical models tell them they should.

Do there continue to be advantages of anchoring expectations when the central bank is constrained by the ZLB? Here too the answer may be yes. Consider the case analyzed by Eggertsson and Woodford (2003). Suppose the natural real interest rate has fallen, pushing the nominal rate to zero. If $r^n_t = \bar{r} < 0$, suppose $r^n_{t+1} = \tilde{r}$ with probability $q$. 

Figure 9: Loss as a function of $\delta$, where $\delta = 0$ is rational expectations and $\delta = 1$ is completely anchored expectations.
Figure 10: Output gap and inflation variances relative to rational expectations as a function of $\delta$, where $\delta = 1$ corresponds to completely anchored expectations. Both the output gap and inflation are more stable when expectations of future inflation are anchored at $\pi^T$.

and reverts to its steady-state value with probability $1 - q$. Assume, as would be the case under discretion, that once $r^n$ returns to its steady-state value, the central bank sets inflation equal to its target rate, consistent with a zero output gap. Expectations are given by (8).\footnote{The equilibrium satisfies
\begin{align*}
x^{zlb} &= qx^{zlb} + \sigma (\pi^e + \bar{\pi}) \\
\pi^{zlb} - \pi^T &= \beta \left( \pi^e - \pi^T \right) + \kappa x^{zlb} \\
\pi s^e &= (1 - \delta) \left[ q \pi^{zlb} + (1 - q) \pi^T \right] + \delta \pi^T.
\end{align*}
I focus on parameter values consistent with a type 1 equilibrium to this system; see Braun et al. (2012).}

Figure 11 shows the output gap $x^{zlb}$ (top panel) and inflation $\pi^{zlb}$ (bottom panel) for $\delta = 0$ (solid line) and $\delta = 1$ (circles) for different probabilities of exiting the ZLB $q$. If the probability of exiting the zero lower bound is high (i.e., $q$ is small), the equilibrium output gap is little affected by $\delta$; agents forming rational expectations place a large weight on the likelihood that $\pi_{t+1}$ will equal $\pi^T$, just as would occur with anchored expectations. However, if the probability of exiting is assessed to be low ($q$ large), the gains from
anchored expectations are clear. By limiting the reinforcing effect of declining expected inflation on actual inflation, and therefore limiting the rise in the real interest rate, both the output gap and inflation fall less at the zero lower bound when expectations of future inflation are firmly anchored at the central bank’s target rate.

Of course, outcomes might be even better if the central bank could promise to keep the nominal rate at zero after the point at which it would normal find it optimal to raise rates. But the case considered here may be the more relevant one.\textsuperscript{17} Further, as discussed by Levin et al. (2010) and Carlstrom et al. (2012), simple NK models like the one considered here have explosive roots when the nominal interest rate is fixed at zero for an extended period, even though there is a unique determinate equilibrium once the nominal rate is increased above zero.\textsuperscript{18}

\textsuperscript{17}Bodenstein et al. (2012) illustrate the dangers of making future promises when these promise are not fully credible.

\textsuperscript{18}See also Jung et al. (2005). Negro et al. (2012) find that the DSGE model they employ (FRBNY-DSGE) implies overly strong movements in the 10-year nominal rate in response to forward guidance about the future short rate. They conclude that DSGE models overestimate the impact of forward guidance about the path of the short rate.
3.1.3 Expectations as automatic stabilizers

Theory suggests simply anchoring expectations is too modest a goal for policy makers, but attempting to use expectations as instruments may strain credibility and represent a form of fine tuning that is too ambitious. Perhaps an alternative is to consider policy regimes in which expectations work as automatic stabilizers, with the endogenous reactions of expectations helping to stabilize the economy. Price level targeting and nominal income targeting are examples of such policy regimes. It may be easier to commit to a goal such as a path for the price level than it is to commit to taking future actions that, at the time they must be taken, will not be optimal from the perspective of the stated goals of the central bank.

If policy makers are better able to commit to policy goals than to behave in the manner called for under optimal commitment policies, then expectations cannot serve as a policy instrument in the manner assumed in many analyzes of what central banks should do at the zero lower bound. If policy makers can follow the optimal commitment policy, then they should do so. But if they can’t, then expectations are best viewed through the perspective of their role as an anchor or an automatic stabilizer and not as a policy instrument.

4 Balance sheet policies

With their traditional interest rate instruments at or near zero, central banks have engaged in a variety of actions, known collectively as quantitative easing, or QE, policies. These policies use the size and/or composition of the central bank’s balance sheet to affect the economy.20

In a financial crisis, among the traditional tools of a central bank is the ability to provide short-term loans to solvent institutions as the lender of last resort. Figure 12 illustrates the balance sheet consequence of the Federal Reserve’s provision of loans to financial institutions and liquidity to key markets during the financial crisis. These actions expanded the balance sheet from its pre-crisis level of roughly $860 billion to a peak in

---

19 See Vestin (2006), Eggertsson and Woodford (2003), Svensson (2003), Billi (2013), Coibion et al. (2012) and Berentsen and Waller (2011) for alternative analyses of price level targeting and nominal income targeting. Berentsen and Waller are explicit about the role expectations play as an automatic stabilizer.

20 See Borio and Disyatat (2010) for a general discussion of monetary policy tools that incorporate balance sheet policies.
December 2008 of just under $2.25 trillion. As one would expect of lender of last resort activity, the crisis created a temporary expansion of the balance sheet that was quickly reversed as financial markets returned to more normal conditions.

In what follows, the focus will be on balance sheet policies that cannot be described as traditional lender of last resort actions. The consequences of these QE policies for the Federal Reserve’s balance sheet are shown in Figure 13, which subtracts lending to financial institutions, the provision of liquidity and the level of traditional security holdings at the beginning of 2007 from the total balance sheet. The resulting figure shows the net change in the Fed’s holdings of government securities and other assets acquired as a result of QE policies. Initially, the Fed financed lending to financial institutions by reducing its holdings of government securities so that the balance sheet net of these components fell. However, in March 2008, this decline was halted and then reversed with the balance sheet continuing to grow, reaching $3.9 trillion in mid-April 2014 when these data were download.

Numerous authors have described in detail the specific nature and timing of each of the Fed’s QE policies. For example, see Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2013) and D’Amico et al. (2012) for the U.S., and Joyce et al. (2011)
for the UK.\footnote{See also http://projects.marketwatch.com/short-history-of-qe-and-the-market-timeline/#0.} Key dates are given in Table 4. It is clear from Figure 13 that the past five years have not witnessed a steady growth in the Fed’s balance sheet. Instead, there have been periods of growth followed by pauses. The first large expansion, under QE1 from November 2008 until March 2010, resulted in the purchase of $300 billion in US Treasuries, $1.25 trillion of agency mortgage backed securities and $170 billion of agency debt. After a pause, the balance sheet expanded again under QE2 which began in November 2010 and lasted until June 2011. QE2 involved the purchases of long-term US Treasuries. From July 2011 until December 2012, the total balance sheet remained relatively constant at around $2.8-2.9 trillion. However, this period saw the Fed alter the composition of its balance sheet by purchasing long-term Treasuries financed by selling short-term Treasuries. This modern-day Operation Twist, or MEP for maturity extension program, began in September 2011 and continued through 2012.\footnote{See Swanson (2011) for a comparison of MEP with the Operation Twist of the 1960s.} September 2012 saw the start of QE3 under which the Fed shifted from announcing a fixed amount of purchases and instead committed to purchasing $45 billion of US Treasuries and $40 billion of MBS per monthly with no end date. QE3 is still ongoing, but the monthly amount to be purchased was reduced by $10 billion in December 2013 and is currently (as of May 1) running at $45 billion per month.

The objective of all these policies has been to promote real economic activity. Only QE1 (9/08-3/2010) was launched before the trough of the Great Recession (in June 2009 as identified by the NBER Business Cycle Dating Committee). Figure 14 shows the US civilian unemployment rate and the periods of QE1, QE2, and QE3 (MEP occurs between QE2 and QE3). While QE1 coincided with a period during which the unemployment rate rose significantly (from 6.1% in Sept. 2008 when QE1 began to 10.1% in October 2010), it had declined only to 9.9% by the time QE1 ended in March 2010. However, given the lags in the real effects of monetary policy, the figure suggests that the policy may have arrested the rise in unemployment and contributed to its subsequent decline. However, with the exception of the one-month rise in the unemployment rate in November 2010 (the month QE2 was launched), the gradual fall in unemployment since its peak appears to have occurred at a fairly constant rate, so the contribution of QE policies on the ultimate objective of these policies is not at all obvious.

While the ultimate purpose of the QE policies may have been to lower unemployment, these policies were undertaken to lower longer-term interest rates which would, in turn,
Figure 13: Total balance sheet minus lender of last resort components, expressed relative to the Fed’s traditional security holdings as of January 2007. Source: FRB Cleveland.

Figure 14: Civilian unemployment rate, Jan 2007-December 2013. Shaded areas are QE1, QE2, and QE3. The MEP program falls between QE2 and QE3 with its end occurring after QE3 began.
stimulate aggregate demand and lead to increased output and employment. Thus any assessment of balance sheet policies must address two separate questions. First, are such policies effective in altering yields? Second, if the answer to the first question is yes, are these changes effective in influencing real economic activity? Most of the empirical work on balance sheet policies has focused on the first question, though the answer to the second is clearly critical. Consequently, I will address the second question first: what interest rates should the Fed be attempting to influence to affect real economic activity? But before doing so, it will be helpful to begin with a simple theoretical framework.

4.1 Balance sheet policies and pricing wedges

As is well known, when assets are valued only for their stochastic payoffs and there are no limits on arbitrage, the asset composition of the central bank’s balance sheet is irrelevant. This was first demonstrated by Wallace (1981) and more recently in the context of a new Keynesian model by Eggertsson and Woodford (2003).

To illustrate the role played by the no-arbitrage assumption, consider an economy with money, one- and two-period government debt, privately issued debt, and capital. Assume the household’s problem is to maximize the expected present discount value of utility subject to a budget constraint given by

\[
y_t + T_t + W_t \geq c_t + p_{1,t}b_{1,t} + p_{2,t}b_{2,t} + m_t + q_t h_t - l_t
\]

where initial wealth plus asset income is

\[
W_t \equiv \left(\frac{1}{1 + \pi_t}\right)(b_{1,t-1} + p_{1,t}b_{2,t-1} + m_{t-1}) + \left[r_t^h + q_t (1 - \delta)\right] h_{t-1} - \left(\frac{1 + r_{t-1}}{1 + \pi_t}\right) l_{t-1}
\]

where \(y\) is labor income, \(c\) and \(h\) are consumption and the capital stock, \(m\) equals real money balances, and \(b_i, i = 1, 2\) are the real holdings of one- and two-period government debt. One-period debt pays off one dollar at maturity and sells at the price \(p_1\) while two-period debt pays off one dollar in two periods and sells for \(p_2\). Private one-period loans are \(l\) (so \(l > 0\) implies the household is a borrower) and carry a nominal interest rate \(i^l\). \(T\) are real transfers from (or to) the government. The one-period riskfree gross nominal interest rate is \(1/p_{1,t}\). The real price of capital is \(q_t\) which depreciates at rate \(\delta\) and earns a rental rate \(r_t^h\).
The Appendix shows the intertemporal budget constraint can be written as

\[ E_t \sum_{i=0}^{\infty} \beta^i \left( \frac{\lambda_{t+i}}{\lambda_t} \right) (y_{t+i} + T_{t+i}) + W_t = E_t \sum_{i=0}^{\infty} \beta^i \left( \frac{\lambda_{t+i}}{\lambda_t} \right) c_{t+i} + \Omega_t, \]  

(10)

where

\[ \Omega_t \equiv E_t \sum_{i=0}^{\infty} \beta^i \left( \frac{\lambda_{t+i}}{\lambda_t} \right) (\Delta_{2,t+i} b_{2,t+i} + \Delta_{m,t+i} m_{t+i} + \Delta_{h,t+i} h_{t+i} - \Delta_{l,t+i} l_{t+i}). \]  

(11)

The left side of (10) is the present value of labor income and transfers plus initial wealth; the right side is the present value of consumption plus the present value of terms that depend on the asset portfolio held by the household. The \( \Delta \) terms are asset specific and equal the wedge between the price of the asset and the discounted value of its future pecuniary payoffs. Equations (10) and (11) can be used to consider various special cases.

Eggertsson and Woodford (2003) assume only money yields non-pecuniary returns, so \( \Delta_2 = \Delta_h = \Delta_l = 0 \). If monetary services enter the utility function, the household, in optimally choosing its money holdings, will ensure

\[ \Delta_{m,t} = 1 - p_{1,t} = \frac{U_{m,t}}{U_{C,t}}, \]

where \( U_m \) is the marginal utility of these services and \( U_C \) is the marginal utility of consumption. In this case,

\[ \Omega_t = -E_t \sum_{i=0}^{\infty} \beta^i \left( \frac{\lambda_{t+i}}{\lambda_t} \right) \left( \frac{U_{m,t+i}}{U_{C,t+i}} \right) m_{t+i}. \]

The offsetting asset in open market operations (OMO) that affect \( m_{t+i} \) are irrelevant. Further, if the nominal interest rate is zero, \( p_{1,t} = 1 \) and \( \Delta_{m,t} = 0 \). As long as interest rates are expected to eventually again be positive, \( \Omega_t \neq 0 \), but whether open market operations (OMO) involve one-period or two-period debt is irrelevant.

The wedge \( \Delta_{2,t} \) is equal to \( p_{2,t} - p_{1,t} E_t p_{1,t+1} \). Under the pure expectations hypothesis of the term structure, \( p_{2,t+i} = p_{1,t+i} E_t p_{1,t+i+1} \) so \( \Delta_{2,t+i} = 0 \) for all \( i \). In this case, \( b_{2,t+i} \) drops out of (10), as Eggertsson and Woodford (2003) assume. Consequently, whether changes in \( m \) are engineered via open market operations involving one-period or two-
period debt is irrelevant. The spirit of a preferred habitat model such as Vayanos and Vila (2009) can be captured by assuming the household’s holdings of the two-period bond directly affect utility. In this case, $\Delta_{2,t} = U_{b,t}/U_{C,t}$ where $U_b$ is the marginal utility derived from long-term bonds. With $\Delta_{2,t} \neq 0$, OMO involving two-period bonds can have effects that are distinct from OMO in one-period bonds. In Chen et al. (2012), some households face transactions costs in holding long-term bonds, so for these households, $\Delta_{2,t}$ would be a function of the transactions costs.

Suppose the household faces a borrowing constraint and let $\theta_t$ is the Lagrangian multiplier on the constraint. If this constraint is binding,

$$\Delta_{t,t} = \frac{\theta_t}{U_{C,t}} \geq 0.$$

Suppose further that the capital asset is housing that provides services that generate utility and that also serves as collateral so that the borrowing constraint is of the form

$$l_t \leq \mu E_t p_{1,t} q_{t+1} h_t; \ 0 < \mu < 1.$$

Then $\Delta_{h,t} = (U_{h,t}/U_{C,t}) + \theta_t \mu E_t p_{1,t} q_{t+1}/U_{C,t}$ and

$$\Delta_{h,t+i} h_{t+i} - \Delta_{l,t+i} l_{t+i} = \left( \frac{U_{h,t+i}}{U_{C,t+i}} \right) h_{t+i},$$

where $U_{h,t}/U_{C,t}$ is the marginal utility of housing. In this case, in the presence of preferred habit preferences and a positive nominal interest rate, (11) becomes

$$\Omega_t = -E_t \sum_{i=0}^{\infty} \beta^i \left( \frac{\lambda_{t+i}}{\lambda_t} \right) \left[ \left( \frac{U_{h,t+i}}{U_{C,t+i}} \right) b_{2,t+i} + \left( \frac{U_{m,t+i}}{U_{C,t+i}} \right) m_{t+i} + \left( \frac{U_{h,t+i}}{U_{C,t+i}} \right) h_{t+i} \right]. \quad (12)$$

Notice that this formulation represents the primary approach to the Ramsey optimal tax problem in which the household’s first order conditions have been used to eliminate prices (the wedges) from the intertemporal budget constraint.\footnote{See Lucas and Stokey (1983).}

When $U_b \equiv 0$, $b_2$ does not appear in (12). Open market operations affecting the time path of $m$ and $b_1$ are equivalent to ones involving $m$ and $b_2$. And, selling short-term government bonds to purchase long-term government bonds is neutral. Issuing money to purchase housing is not. If there are preferred habitat effects ($U_b \neq 0$), then it matters...
whether $m$ is expanded to purchase short-term or long-term government debt. Also, changing the maturity composition of the government debt held by the private sector matters because the time path of $b_2$ enters the household’s budget constraint. If the nominal interest rate is zero, $U_m = 0$ and $m_{t+j}$ does not appear in (12) for period $t+j$ for which the nominal rate is at zero. But $m_{t+j+i}$ does still appear for future periods when nominal rates have risen above zero. If $U_b \neq 0$, debt maturity changes can still matter when rates are at zero.

If all households are identical, inside financial assets/liabilities such as $l$ drop out when (10) is aggregated. This means that even though $\left[ (1 + i_{t-1}) / (1 + \pi_t) \right] l_{t-1}$ appears in $W_t$, current inflation does not generate Fisher-debt-deflation effects. When there is heterogeneity among households, then current inflation has distributional effects when debt is in nominal terms.24

These examples ignore the adjustment of transfers to the private sector that would potentially occur as shifts between interest bearing and noninterest bearing government liabilities carries fiscal implications with it.

What (12) serves to point out is that understanding the way in which the central bank’s balance sheet has real effects depends critically on understanding the sources of the wedges and how they depend on the composition of assets held by the public. The wedges reflect limitations to arbitrage, transaction costs, non-pecuniary returns, segmentation in financial markets, and/or any other factor that leads assets effectively to be imperfect substitutes25 and current asset prices to differ from the asset’s discounted future pecuniary payoffs.

The effects of the Fed’s QE policies on asset prices, as discussed below, challenges the pre-crisis theoretical paradigm that treated all the wedges except $\Delta_m$ as equal to zero. Recent models have introduced wedges in a variety of ways, for example, by assuming restrictions on portfolio choice (segmented markets, moral hazard, resaleability constraints) that limit arbitrage opportunities, by introducing transactions costs on certain assets, or by assuming preferred habitat effects (Andrés et al. (2004), Vayanos and Vila (2009), Negro et al. (2011), Chen et al. (2012), Carlstrom et al. (2014), Gertler and Karadi (2011), Gertler and Karadi (2013a), and Gertler and Karadi (2013b)).

---

24 For a recent DSGE model in which inflation effects on the real value of outstanding nominal debt plays a role, see Carlstrom et al. (2014). See also Eggertsson and Krugman (2012).

25 The relevant substitution effects are Hicksian $q$-substitution effects rather than standard $p$-substitution effects; see Walsh (1982).
As D’Amico et al. (2012) note, the expectations hypothesis of the term structure and skepticism about portfolio balance effects dominated the pre-crisis academic literature and policy discussions. If assets are imperfect substitutes, then the effects of QE policies on asset prices other then on the assets directly purchased by the central bank will depend on the degree to which the assets the central bank purchases are close substitutes for other assets. The effects will be small if asset markets are highly segmented and/or the assets involve are very imperfect substitutes for other assets. Thus, central bank purchases of long-term government securities financed by sales of short-term Treasuries, for example, will have little effect on corporate yields if short-term and long-term Treasuries are close substitutes (as then only the total outstanding stock effectively matters) or if long-term Treasuries and corporate bonds are very imperfect substitutes (Walsh (1982)).

4.2 Which rates or spreads are relevant?

Is reducing the long-term rate on U.S. Treasuries sufficient for stimulating economic activity? Or is it more important to reduce risk premiums reflected in corporate bond rates? To answer these questions, consider a forecasting equation for real economic activity of the form

\[ Y_{t+h} - Y_{t-1} = \alpha + \sum_{i=1}^{k} (Y_{t-i} - Y_{t-1-i}) + \gamma_1 RFF_t + \gamma_2 \left( i_{t}^{10yr} - i_{t}^{3mon} \right) \]

\[ + \gamma_3 \left( i_{t}^{Aaa} - i_{t}^{10yr} \right) + \gamma_4 \left( i_{t}^{Baa} - i_{t}^{Aaa} \right) \]  \hspace{1cm} \text{(13)}

where \( Y \) is the measure of economic activity, \( RFF = i_{t}^{ff} - 100(\log p_t / \log p_{t-12}) \) where \( p \) is the PCE index less food and energy, \( i_{t}^{10yr} - i_{t}^{3mon} \) is a term spread and \( i_{t}^{Aaa} - i_{t}^{10yr} \) and \( i_{t}^{Baa} - i_{t}^{Aaa} \) are credit spreads. Equation (13) is similar to forecasting equations estimated by Gilchrist and Zakrajšek (2012), though they focus on a number of alternative credit spreads. Rudebusch (2007) also estimates similar equations and summarizes the literature. The measures of economic activity are industrial production, and the unemployment rate, with the log change in industrial production expressed at annual rates.\(^{26}\) Forecast horizons are 3 months and 12 months.

Tables 5 and 6 present results for (log) industrial production (Table 5) and the un-

\(^{26}\)Gilchrist and Zakrajšek (2012) also use payroll employment and estimate forecasting equations for real GDP using quarterly data.
employment rate (Table 6). Samples begin in 1962:1 and also in 1985:1 to capture only the period beginning with the Great Moderation. The samples end either in 2007:12 or utilize data up to 2014:2 (exact end date depends on the forecast horizon). I focus on three spreads: the 10 year rate minus the 3-month month rate on constant maturity Treasury securities and the spreads between the Aaa rate and the 10 year Treasury rate and that between the Baa rate and Aaa rate. The first spread captures the slope of the term structure, reflecting both expectations of the path of future short rates and the pure term premium, while the second two captures risk factors.

The coefficients on the real funds rate variable are of the expected signs (negative for industrial production, positive for unemployment) and generally statistically significant, though not for industrial production using samples beginning in 1985.27 More interestingly, given the Fed’s focus in reducing term premiums and the importance of the long-term Treasury rate in discussions of forward guidance at the ZLB, increases in the term spread forecast higher future industrial production at all horizons and lower future unemployment, with coefficient estimates being statistically significant for all samples.

The finding that a rise in the long-rate relative to the short-rate predicts higher future real activity is consistent with the evidence discussed by Rudebusch (2007), though he argues that if changes in spreads are used, rather than levels, a rise in the long rate predicts slower future growth. Re-estimating (13) with the change in the term spread and risk spreads (results not reported), I find that the signs of the coefficients do change for industrial production, as found by Rudebusch (2007), but not for unemployment and none of the coefficients on the change in the term premium measure, either for industrial production or unemployment, were statistically significant.

Turning to the Aaa – 10 year and Baa – Aaa spreads, a rise in either predicts weaker future industrial production and higher unemployment. The estimated coefficients on Aaa – 10 year are highly statistically significant except for the 12-month forecast

27Note that a typically linearized Euler equation in a basic NK model would imply

\[ y_{t+1} - y_t = a \left( i_t - \pi_{t+1} - \pi_t^e \right) + \phi_{t+1}, \]

where \( \phi_{t+1} \) is a forecast error term equal to

\[ y_{t+1} - E_t y_{t+1} - a \left( \pi_{t+1} - E_t \pi_{t+1} \right). \]

The coefficient on the real interest rate in this expression is positive - a rise in the real rate is associated with faster economic growth. However, this faster growth is generated by an immediate drop in \( y_t \). In the regressions of Tables 5 and 6, the dependent variable involves \( y_{t+h} - y_{t-1} \), i.e., not \( y_t \).

35
equations for unemployment. Those on $Baa - Aaa$ are not statistically significant in the unemployment equations except when the sample extends to include the Great Recession and subsequent recovery.

The results in Tables 5 and 6 suggest a focus on reducing term premiums may be misguided as a means of stimulating economic activity. Instead, the objective should be to reduce risk spreads between private debt and government debt. However, spread movements are endogenous; over most of the sample period, it may be that the term premium rises when future economic growth is expected to be stronger. If so, term (and risk) premiums may be related in quite different ways with future activity than when the movements are generated by policy actions such as QE policies.

### 4.2.1 Monthly VAR evidence

To explore further the effects of movements in spreads and real economic activity, I use monthly data to estimate VARs that include a measure of real economic activity, the real funds rate, and two interest rate spreads. Real economic activity is measured by the (log) index of industrial production and the civilian unemployment rate. The real federal funds rate is the effective federal funds rate minus actual inflation over the previous twelve months as measured by the core PCE index. The two spreads are the spread between the 10-year Treasury rate and the 3-month Treasury rate and the spread between the Baa corporate bond rate and the 10 year Treasury rate. Thus, the first spread is a measure of risk-free term premium while the second captures risk factors.\(^{28}\)

Table 7 reports significance levels for F-tests of the null hypothesis that the coefficients of a variable are zero in the equation for log industrial production (columns 1-5) or unemployment (columns 6-10). Columns 1 and 6 are estimated over the full sample while the remaining results are from the sample ending 2007:12. The findings for the two spreads are consistent across all columns; the riskfree term spread between long and short Treasury rates is never statistically significant. In contrast, the risk spread captured by the difference between the Baa rate and the 10 year Treasury rate is always significant. On the face of it, this suggests operations designed to twist the term structure – lowering the long-term Treasury rates while the short-term rate is fixed at zero – may have little expansionary effect on real economic activity unless they also lower risk spreads.

\(^{28}\) A lag of 6 for all the VARs was chosen by the AIC criterion. A constant, trend and trend squared are included in all VARS.
Figure 15: Impulse response functions based on monthly VAR for full sample (blue) and sample ending in 2007:12 (red). (versions 9 (full sample) and 5 (shorter sample))

Figure 15 shows the impulse responses of industrial production and the unemployment rate to shocks to the real funds rate measure and the two spreads. Blue lines are from the full sample, while the red lines are from the sample that ends in 2007:12. Dashed lines are 90% confidence bands. As expected, a positive innovation to the real rate is contractionary, lowering industrial production and raising the unemployment rate.

The results of section 2.1 suggested that the nominal interest rate may not enter simply in the form of the real interest rate, so columns 3 and 8 of Table 7 report results with the (ex-post) real funds rate replaced by the nominal funds rate, while columns 4 and 9 include both. Because the funds rate has been fixed at essentially zero in recent years, these estimates are based on the sample that ends in 2007:12. The nominal funds rate is significant in the equations for industrial production and the unemployment rate (cols. 3 and 8). When both the real rate and the nominal rate are included (cols. 4 and 9), only the nominal rate is significant in the unemployment equation. In any case, the term premium is never significant, while the measure of the risk premium always is.
4.3 Which rates were affected?

The evidence in the previous section suggests that to be effective, QE policies need to reduce risk premiums. Reductions in the term premium are estimated to have contractionary effects on economic activity, though these effects are generally insignificant. This returns us to the first question posed earlier: which rates have the various QE policies affected?

Table 8 reports results from regressing two-day changes for various interest rates on a set of dummy variables equal to one on dates identified with significant news about the Fed’s QE programs.\textsuperscript{29} The sample period runs from Jan. 7, 2008 to March 11, 2014. The dates for QE1 (LSAP-I), QE2 (LSAP-II), and MEP (maturity extension program) are from Krishnamurthy and Vissing-Jorgensen (2013). For QE3, the dates are September 13, 2012 when the program of $40 billion per month of mortgage backed securities was announced, while MEP was also continued, increasing the Fed’s holdings of long-term Treasuries by $45 billion per month, and December 12, 2012 when it was announced the Fed would continue its purchases of $45 billion of long-term Treasuries per month after MEP ended. In addition, three dates in 2013 associated with the Fed’s tapering of their monthly rate of asset purchases are included. These are June 19, when Chairman Bernanke’s statement was interpreted widely as indicating that tapering would begin in September, September 18, the date of FOMC meeting at which it was decided not to taper, and December 18, the date of the FOMC meeting at which it was decided that purchases would be reduced from $85 billion per month to $75 billion. Results are shown for 2-day changes in 5- and 10-year constant maturity Treasuries, Aaa and Baa corporate bond rates, the 10 year - 3 month spread on constant maturity Treasuries, Aaa-10year and Baa-10 year spreads. Because this exercise uses zero/one dummies, it cannot provide any estimate of the quantitative impacts scaled by the size of the relevant program. Instead, it simply assess the direction rates moved on the day of the announcements and the statistical significance of the effects.

Taking each QE program in turn, QE1 (LSAP-I), associated with purchases of agency debt and agency MBS and Treasuries securities, was associated with statistically signifi-
cant declines in the 10-year Treasury rate as well as the Aaa bond rate. The Baa rate is also estimated to have decline, with the effect significant at the 10% level. So while the term structure flattened (the 10 year rate fell relative to the 3 month rate), risk spreads as captured by the spread between the Aaa bond and Baa rates and the 10 year rate rose, not the changes were not statistically significant.

The estimated average effects of QE2 (LSAP-II) were felt primarily in a fall in the 10 year Treasury rate. The effects on corporate bonds rates were statistically insignificant. The Fed’s maturity extension program, or MEP, was a direct attempt to twist the term structure by purchasing long-term government debt financed by selling short-term government debt. Thus, this policy was designed to alter the composition of the Fed’s balance sheet rather than to expand its overall size (see figure 13). The effects of MEP were statistically significant on all yields and spreads shown in the Table. Consistent with the twisting objective, the rate on 5-year Treasury securities rose while the rate on 10-year Treasuries declined. Both the Aaa rate and the Baa rate fell significantly so that the Baa-10yr spread fell modestly.

Finally, QE3 involved the announcement on September 13, 2012 of an open-ended policy of purchasing agency MBS’s in the amount of an additional $40 billion per month. At the FOMC meeting in December 2012, this rate was increased to $85 billion per month. QE3 is estimated to have had a statistically significant positive effect on the 10-year rate. The Aaa rate and the Baa rate also rose on the QE3 dates, and the effects are statistically significant. The term spread rose significantly though the Baa-10 year spread fell. These effects are shown in figure 17.

The different effects on rates and spreads of the QE announcements on the 10-year, Aaa and Baa rates and spreads are shown visually in figures 16 and 17.

The last three events included in the event study all occurred during the second half of 2013. On June 19, 2013 at Chairman Bernanke’s press conference, he stated that the FOMC’s more optimistic economic forecast might mean that “it would be appropriate to moderate the monthly pace of purchases later this year,” and went on to state: “And if the subsequent data remain broadly aligned with our current expectations for the economy, we would continue to reduce the pace of purchases in measured steps through the first half of next year, ending purchases around mid-year.” The sooner-than-expected tapering

---

30Based on one-day changes, the declines in the 1-year, 5-year, and Baa rates were also significant, while the change in the Baa-10yr spread was positive and significant.

31The rise in the Baa-10year spread was significant at the 10% level using a one-day window.
Figure 16: Two day changes in rates associated with QE announcements.

Figure 17: Two day changes in spreads associated with QE announcements.
of QE3 caused a significant reaction on financial markets; see figure 18. As Table 8 shows, rates across the maturity and risk spectrum rose, though the primary effect was on the term spread (see figure 17). When, at its September meeting, the FOMC did not taper its purchases, the effects were to lower rates (compare rows 5 and 6 of the table). When, at its December meeting, the FOMC actually did announced a tapering of purchases, rates rose.

To summarize, the two day change in rates around QE announcements dates varied across the different QE programs. QE1, QE2 and MEP announcements are estimated to have had statistically significant negative effects on the term premium. In contrast, QE3 raised the term premium. QE2 had statistically significant positive effects on the spreads of Aaa and Baa bonds over 10 year Treasuries. MEP raised the Aaa – 10yr spread but lowered the Baa – 10yr spread while QE3 announcements lowered the latter spread. Given the findings in section 4.2, it appears the first two QE policies did not affected the spreads most relevant for real economic activity.
4.3.1 Review of the literature on financial market effects

The regressions summarized in Table 8 provide summary evidence on the effects of QE announcements without discriminating among the various channels through which rates might have been affected. Investigating alternative channels has been the objective of much of the existing empirical literature. For example, Krishnamurthy and Vissing-Jorgensen (2013) distinguish between capital constraint, MBS scarcity, safety premium, duration risk premium and signally channels, while D’Amico et al. (2012) distinguish between scarcity (preferred habitat), duration (interest rate risk) and signalling channels. D’Amico et al. (2012) make the important point that determining which of these channels is most important can help guide the development of macro models. However, there is, to date, no work investigating which of these channels are the ones most important for economic activity.

One of the first and most influential analyses of the Fed’s LSAP policies is the work

---

32 Table 1 p. 10 of Krishnamurthy and Vissing-Jorgensen (2013) provides a summary of their findings for the LSAP programs. Note that they include 9/12/2012 as the single date for QE3. In Table 8, 12/12/2012 is also counted as a QE3 date.

33 I restrict attention here to studies of the Fed’s QE policies. Papers that focus on the Bank of England’s policies include Joyce et al. (2011) and Kapetanios and Muntaz (2012). As noted previously, Christensen and Rudebusch (2012) also estimate the effects of QE policies in the UK.
of Gagnon et al. (2011). They “find that LSAPs causes economically meaningful and long-lasting reductions in longer-term interest rates on a range of securities, including securities that were not included in the purchase programs.” They also conclude that the policies reduced risk premiums rather than expectations of future short rates (p. 5). This suggests a low degree of substitutability between reserves and assets purchased (long-term Treasuries and MBS) and a high degree of substitutability between the assets purchased and corporate debt.

Krishnamurthy and Vissing-Jorgensen (2013) conclude, somewhat in contrast to Gagnon et al. (2011), that “The portfolio balance channel of QE works largely through narrow channels that affect the prices of purchased assets, with spillovers depending on particulars of the assets and economic conditions. It does not, as the Fed proposes, work through board channels such as affecting the term premium on all long-term bonds.” (p. 1)\textsuperscript{34} This is an important finding since it means effects are dependent on the particular assets involved and suggests QE policies are not good substitutes for general changes in the level of interest rates when the policy rate itself can be used. It also may suggest that the level of segmentation in financial markets is particularly high, limiting the arbitrage across broad categories that is implicitly assumed by arguments that lowering long-term rates on Treasuries will have effects on a wide range of asset prices.

A number of authors have used term structure factor models to investigate the effects of bond supply on interest rates (for example, Li and Wei (2013), Greenwood and Vayanos (2008), Hamilton and Wu (2012), D’Amico et al. (2012), Swanson (2013)). If financial assets are imperfect substitutes in investors’ portfolios, then changes in the outstanding stocks of these assets should cause relative rates of return to adjust. Hamilton and Wu (2012) echo the much earlier work by Bernanke et al. (2004) in stating that “Our conclusion is that although it appears to be possible for the Fed to influence the slope of the yield curve in normal times ....very large operations are necessary to have an appreciable immediate impact. If there is no concern about a ZLB constraint, this potential tool should clearly be secondary to the traditional focus of open market operations on the short end of the yield curve.” (p. 24). D’Amico et al. (2012) reach a more positive conclusion in arguing that changes in debt stocks affect yield independent of any signalling effects and that their results “affirm the potency of LSAPs as a monetary policy tool.”

Even in the absence of portfolio balance effects arising from investor heterogeneity

\textsuperscript{34}See also Krishnamurthy and Vissing-Jorgensen (2011).
or segmented markets, long-term yields could be affected by QE policies if these policies provide new information about the future path of short-term interest rates. This signaling channel is the only channel that operates in pure expectations models of the term structure. Christensen and Rudebusch (2012) and Bauer and Rudebusch (2013) argue that the commonly used Kim-Wright estimate of the term premium, the estimate used in several of the studies of QE policies, is based on a model in which the short-rate speed of reversion is overstated. Hence, work using the Kim-Wright model of the term premium, such as Gagnon et al. (2011), will tend to over attribute movements in the long-rate due to QE to movements in the term premium rather than to persistent movements in expected future short rates. Bauer and Rudebusch (2013) argue the effects of QE policies on L-T rates in US and UK similar but via worked through the signally channel in the U.S. and entirely due to declines in term premium in the UK. They attribute these differences to a greater focus on providing forward guidance in the communications of the Fed.

While much of literature has focused on the effects of LSAPs on Treasury yields, Gilchrist and Zakrajšek (2013) focus on the default risk channel by looking at effects on measures of corporate credit risk. If LSAPs help stimulate the economy, expected defaults should fall, reducing the default risk premium and increasing investor appetite for risk. They argue that event study estimates of LSAP are biased downward due to endogeneity of interest rate and credit risk responses to common shocks. They identify the credit risk the response to QE policies using shifts in the variance of monetary policy shocks on announcement dates, based on the premise that a larger share of news is associated with monetary policy on these dates. Gilchrist and Zakrajšek (2013) conclude that declines in riskfree rates due to LSAP programs “...led to economically large and statistically significant reductions in the CDX indexes, both for the investment and speculative-grade segments of the U.S. corporate sector.” (p. 5) CDX is tradeable credit derivative index. But they also find “...the LSAP announcements – somewhat to our surprise – had no measurable effect on credit risk in the financial intermediary sector.” (p. 5)

4.4 QE effects in DSGE models

While most studies of QE have focused on financial markets, understanding their impact on asset prices and yields provides at best a partial answer to the question of whether these policies have been effective in supporting economic growth. Estimating such effects

---

35 Wright 2012 uses similar approach.
is inherently much more difficult that estimating the effects of announcements on asset yields. Several authors have utilized DSGE models to simulate the effects of QE policies. For example, Chen et al. (2012), building on the work of Andrés et al. (2004), simulate the effects of a QE program in a DSGE model with segmented financial markets and a transactions cost that limits arbitrage. This transactions costs appears as a wedge between one-period returns on the short-term and long-term government bonds, as only the latter are subject to these cost.\footnote{While this wedge is called a risk premium by Chen et al. (2012), it is solely due to the transactions fee associated with buying or selling long-term bonds and therefore does not reflect risk factors.} A fraction of households are restricted to hold only long-term bonds, but pay no transactions fees to do so. Because they assume these transactions costs depend on the maturity structure of publicly held government debt, debt management operations or open market operations that alter the ratio of long-term to short-term debt held by the public also alter the transaction cost wedge between long-rates and short-rates. The resulting interest rate adjustments affect consumption behavior and real economic activity. Interestingly, when they estimate the model using U.S. data, they find relatively little evidence of market segmentation.\footnote{The 90% interval for the posterior distribution of the estimated fraction of unrestricted households is [0.82 0.99].} This conclusion seems to be in contrast with that of Krishnamurthy and Vissing-Jorgensen (2013).

The results of Chen et al. (2012) seem consistent with earlier findings that very large QE policies are necessary to move interest rate premiums significantly.\footnote{For example, they estimate that a commitment to keep the short-term rate at zero for 4 quarters combined with an LSAP of $600b raises GDP growth by 0.13% at an annual rate and increases inflation by 3 basis points. The effects of LSAP similar to 25 basis point cut in the short-term rate, but (see Figure 5, p. 313) it is interesting that the interest rate cut has a larger impact on GDP growth but only a tiny impact on the 10 year rate, raising questions about the transmission channel of monetary policy in the model.} They conclude “Asset purchase programmes are in principle effective at stimulating the economy because of limits to arbitrage and market segmentation between short-term and long-term government bonds. The data, however, provide little support for these frictions to be pervasive.” (Chen et al. (2012) p. F313).

Another example of a DSGE model developed to investigate QE policies is that of Carlstrom et al. (2014). Their model incorporates market segmentation and, because of moral hazard issues, the net worth of financial intermediaries limits the ability of these institutions to arbitrage away the spread between long rates and deposit rates. They also assume that new investment is financed with long-term nominal debt, arguing that this
leads to larger effects of QE policies because investment is more interest sensitive than
is the consumption spending that is the focus of the segmented market’s model of Chen
et al. (2012).39 Financial intermediaries are the sole purchasers of long-term government
bonds and investment bonds, but these are perfect substitutes from perspective of the
intermediaries, so they carry same yield. Thus, QE policies that lower long-term rates
on government debt automatically lower interest rates on private debt used to finance
investment. On the other hand, the assumption of segmentation “decouples the short
rate from the rest of the term structure.” They conclude that (i) there are welfare gains
to having central bank respond to term premium in a Taylor rule, (ii) the sign of response
though depends on type of shocks, (iii) the term premium response to monetary policy
shocks depends importantly on whether existing debt is indexed, and (iv) a policy that
targets the term premium “sterilizes the real economy from shocks originating in the
financial sector.” As they recognize, this last point is similar to the findings of Poole

4.5 Summary

The objective of the Fed’s QE policies has been to promote real economic activity. The
evidence that risk spreads, and not term spreads, are the most relevant for output and em-
ployment suggests that policies aimed specifically at lowering long-term Treasury yields
will have significant expansionary effects only if Treasuries and risky assets are close sub-
stitutes. The evidence is mixed. Krishnamurthy and Vissing-Jorgensen (2013) conclude,
“The Fed’s purchases of long-term US Treasury bonds significantly raised Treasury bond
prices, but has had limited spillover effects for private sector bond yields, and thus lim-
ited economic benefits.” (p. 2) and “The portfolio balance channel of QE ....does not,
as the Fed proposes, work through broad channels such as affecting the term premium
on all long-term bonds.” (p. 1). In contrast, Gilchrist and Zakrajšek (2013) find QE
announcements reduced credit risk in the nonfinancial sector.

Policies that affect risk premiums would appear to have the potential to have signi-
ficant real effects, but recent DSGE models used to study QE policies actually assume an
absence of risk premiums. For example, interest wedges in Chen et al. (2013) are due to
transactions costs, not risk, and Carlstrom et al. (2014) assume financial intermediaries
view long-term government bonds and private debt as perfect substitutes, implying the

39Since debt is issued in nominal terms, inflation has real effects even with flexible prices.
interest spread between the two is zero.

5 Aggregate supply effects

The discussion so far has adopted the traditional approach of focusing on the transmission of monetary policy through interest rates and asset prices to its effects on real aggregate spending. Many models, though, also include supply-side effects of monetary policy, with these effects again arising from the effects of policy on interest rates and asset prices. For example, if investment spending is affected through standard interest rate channels, monetary policy will alter the future path of the capital stock. Expansionary monetary policy, in this case, increases future productivity by increasing the level of capital. Typically, these capital stock effects on aggregate supply are ignored, or are viewed as of second order importance. As is well known from the real business cycle literature, cyclical fluctuations in investment generates very little effect on the aggregate capital stock and on the dynamic adjustment of the economy.

Investment in capital is not the only channel through which monetary policy may have supply side effects. Standard models of unemployment emphasize that a job is an ongoing relationship between the worker and the firm. Changes in interest rates affect the continuation value of these relationships; a fall in interest rates raises the present value of the future surpluses generated by an employment match. This reduces endogenous separations by raising the continuation value of the match and it increases the incentives for firms to post more job vacancies. Just as with investment, interest rates affect the firm’s demand for the factors of production. Ravenna and Walsh (2012) show how monetary policy affects markups in ways that also directly affect the job creation condition.

As recently emphasized by Hall (2014), the relevant discount rate for job creation is not the riskfree rate but a rate that reflects the risks associated with the future profit stream accruing to the firm from hiring a new worker. In normal times, expansionary monetary policy lowers riskfree interest rates, and this also reduces the discount rate applied to risky future profit flows. In a financial crisis, however, the riskfree rate may fall, but if risk premiums rise, the incentive to create jobs will fall. Chodorow-Reich (2014) provides firm level evidence of the effects of credit disruptions, suggesting that the cost of credit may not be the only relevant measure.

Search frictions in labor markets are not the only means by which interest rates have
supply-side effects. The need to finance working capital or wage bills in advance of receiving the revenue from production generate cost channel effects (e.g., Chari, Christiano, and Eichenbaum 1995, Ravenna and Walsh (2006)). The presence of these effects means that an increase in finance costs can reduce demand while also raising firms’ marginal cost. As a result, the effects of policy on inflation can be muted. Christiano et al. (2014) argue that these channels help explain the stability of inflation since 2008 in the face of a large output gap. By preventing inflation from otherwise declining, further increases in real interest rates have been avoided at the ZLB.

New Keynesian models, in common with most monetary policy frameworks used by mainstream academics for the past 40 years, incorporate the assumption that monetary policy exhibits long-run real neutrality. This is reflected in the use of models that focus only on fluctuations around a steady-state or trend path that is itself independent of monetary policy. Thus, monetary policy is assumed to have, potentially, important effects on short-run fluctuations in real economic activity but to have no effect on either average real growth rates or the average level of real income.

In general, these supply-side effects are assumed to be transitory. Let me mention three channels through which the average rate of inflation might have permanent effects on the level of real economic activity. First, trend inflation affects the average real output level in models with costly price adjustment. See Ascari and Sbordone (2013). However, Levin and Yun (2007) show how the frequency of price adjustment changes with changes in trend inflation, potentially muting any real effects. Second, downward nominal wage rigidity can impart a slope to the long-run Phillips curve at low average rates of inflation. See Benigno and Luca (2011) and Daly and Hobijn (2013); the latter prices evidence from the U.S. CPS. However, Coibion et al. (2012) find that optimal average inflation is still quite low when wages are downwardly rigid. Third, a low average rate of inflation increases the frequency with which the central bank will find itself constrained by the zero lower bound. With policy more effective in limiting expansions than contractions, the average output gap will be negative, not zero. However, this effect depends on the manner in which monetary policy is conducted; Billi (2011) finds optimal inflation remains low under price level targeting or with a simple inertial interest rate rule.
6 Implications for monetary policy

The results of this paper offer a somewhat cautionary lesson for central bankers. Current models impose strong restrictions governing how nominal interest rates and expected inflation affect aggregate demand. Understanding the empirical veracity of these restrictions is important, particularly at the ZLB as policies such as forward guidance presume these restrictions are correct. And while signalling future actions is important at the ZLB, the role of explicit forward guidance away from the ZLB is less clear. If policy is implemented in a systematic manner that is understood by the public, then forward guidance would only be affective if the central bank planned to deviate in the future from this systematic behavior. But a tool used only when policy will deviate from its customary path is, almost by definition, not a tool that can be used on a regular basis.

Most of the literature on forward guidance and balance sheet policies has assumed that reducing the risk-free term premium is sufficient to establish that such policies are effective in promoting real economic activity at the ZLB, yet risk premiums rather than term premiums seem to be of primary importance for future real economic activity. The evidence clearly suggests QE policies can affect the slope of the term structure. However, there is still only a limited literature that addresses under what circumstances the central bank should use its portfolio to twist the term structure when the policy rate is not at zero. Addressing this issue will require a better understanding of how asset pricing wedges depend both on exogenous shocks and endogenously on monetary policy actions. The evidence from QE policies shows these wedges exist. For three decades, macroeconomics, by and large, ignored these wedges; understanding them is now a critical item on the monetary policy research agenda.

References


Daly, M. C., Hobijn, B. 2013. Downward Nominal Wage Rigidities Bend the Phillips Curve.


Gertler, M., Karadi, P. 2013a. QE 1 vs. 2 vs. 3...: A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool. International Journal of Central Banking, 5–53.

Gertler, M., Karadi, P. 2013b. QE1 vs. 2 vs. 3...: A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool. International Journal of Central Banking, 9, 5–53.


Gilchrist, S., Zakrajšek, E. 2013. The Impact of the Federal Reserve’s Large-Scale Asset Purchase Programs on Corporate Credit Risk. Journal of Money, Credit and Banking.


Gorodnichenko, Y., Kueng, L., Silvia, J., Coibion, O. 2012. Innocent Bystanders? Monetary Policy and Inequality in the US.


Hall, R. E. 2014. High Discounts and High Unemployment.


Negro, M. D., Giannoni, M., Patterson, C. 2012. The forward guidance puzzle. FRB of New York Staff . . . .


Raskin, M. D. 2013. The effects of the Federal Reserve’s date-based forward guidance.


54

Woodford, M. 2012. Methods of policy accommodation at the interest-rate lower bound. Jackson Hole symposium, August, Federal Reserve . . . .

Table 1: Iacoviello and Neri model (AEJ Macro 2011)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Distribution</th>
<th>Prior</th>
<th>Posterior Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_0$</td>
<td>Normal</td>
<td>0 1</td>
<td>Mean</td>
</tr>
<tr>
<td>$\gamma_1$</td>
<td>Normal</td>
<td>0 1</td>
<td>Mean</td>
</tr>
<tr>
<td>$\gamma_2$</td>
<td>Normal</td>
<td>0 1</td>
<td>Mean</td>
</tr>
</tbody>
</table>

* Significant at the 10% level.

Table 2: The Rudebusch-Svensson (1999) model for output

<table>
<thead>
<tr>
<th>Dependent variable: $y_{t-1}^{cho}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>$y_{t-1}^{cho}$</td>
</tr>
<tr>
<td>$y_{t-2}^{cho}$</td>
</tr>
<tr>
<td>$\bar{\pi}<em>{t-1} - \pi</em>{t-1}$</td>
</tr>
<tr>
<td>$\bar{\pi}_{t-1}$</td>
</tr>
<tr>
<td>$\pi_{t-1}$</td>
</tr>
<tr>
<td>$H_0$ sig level</td>
</tr>
<tr>
<td>SE</td>
</tr>
<tr>
<td>DW</td>
</tr>
</tbody>
</table>

Standard errors below coefficient estimates.
### Table 3: The Rudebusch-Svensson (1999) model for output: SPF(2)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y_{t-1}^{ cbo} )</td>
<td>1.10</td>
<td>1.05</td>
<td>1.14</td>
<td>1.08</td>
<td>1.24</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.10)</td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.07)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>( y_{t-2}^{ cbo} )</td>
<td>-0.24</td>
<td>-0.21</td>
<td>-0.23</td>
<td>-0.22</td>
<td>-0.30</td>
<td>-0.31</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.09)</td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.07)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>( \bar{\pi}<em>{t-1} - \pi</em>{t}^{spf} )</td>
<td>-0.12</td>
<td>-010</td>
<td>-0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \bar{\pi}_{t-1} )</td>
<td>-0.12</td>
<td>-0.09</td>
<td>-0.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \pi_{t}^{spf} )</td>
<td>-0.01</td>
<td>-0.03</td>
<td>-0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( H_o ) sig level</td>
<td>0.0061</td>
<td>0.0009</td>
<td>0.1665</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>0.692</td>
<td>0.648</td>
<td>0.564</td>
<td>0.526</td>
<td>0.580</td>
<td>0.576</td>
</tr>
<tr>
<td>DW</td>
<td>2.04</td>
<td>2.05</td>
<td>2.06</td>
<td>2.08</td>
<td>2.10</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Standard errors below coefficient estimates.

### Table 4: Key QE dates

<table>
<thead>
<tr>
<th>QE1</th>
<th>Nov. 2008</th>
<th>Purchase of L-T Treasuries, MBS, agency debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2009</td>
<td>QE1 Expanded</td>
<td></td>
</tr>
<tr>
<td>March 2010</td>
<td>QE1 ended</td>
<td></td>
</tr>
<tr>
<td>QE2</td>
<td>Nov. 2010-June 2011</td>
<td>Purchase of US Treasuries</td>
</tr>
<tr>
<td>QE3</td>
<td>Sept 2012-ongoing</td>
<td>Purchase of $85 billion/month of L-T Treasuries and MBS.</td>
</tr>
<tr>
<td>Tapering</td>
<td>6/6/2013</td>
<td>Bernanke speech suggesting tapering to start in Sept.</td>
</tr>
<tr>
<td></td>
<td>9/18/2013</td>
<td>FOMC does not begin taper</td>
</tr>
<tr>
<td></td>
<td>12/18/2014</td>
<td>FOMC begins taper</td>
</tr>
</tbody>
</table>
Table 5: Forecasting equations – Industrial production

<table>
<thead>
<tr>
<th></th>
<th>3 months</th>
<th></th>
<th></th>
<th>12 months</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Real FF</td>
<td>-0.534</td>
<td>-0.447</td>
<td>-0.125</td>
<td>-0.168</td>
<td>-0.798</td>
<td>-0.652</td>
<td>-0.049</td>
</tr>
<tr>
<td></td>
<td>[3.73]</td>
<td>[3.84]</td>
<td>[0.68]</td>
<td>[0.98]</td>
<td>[11.80]</td>
<td>[9.59]</td>
<td>[0.40]</td>
</tr>
<tr>
<td>T10yr-3mon</td>
<td>1.212</td>
<td>1.363</td>
<td>0.677</td>
<td>0.785</td>
<td>0.889</td>
<td>1.071</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>[4.14]</td>
<td>[5.49]</td>
<td>[2.76]</td>
<td>[3.45]</td>
<td>[6.25]</td>
<td>[7.92]</td>
<td>[4.65]</td>
</tr>
<tr>
<td>Aaa-T10yr</td>
<td>-2.389</td>
<td>-2.914</td>
<td>-1.618</td>
<td>-1.509</td>
<td>-1.618</td>
<td>-2.515</td>
<td>-0.83</td>
</tr>
<tr>
<td></td>
<td>[4.55]</td>
<td>[6.50]</td>
<td>[2.47]</td>
<td>[2.28]</td>
<td>[4.66]</td>
<td>[7.55]</td>
<td>[1.78]</td>
</tr>
<tr>
<td>Baa - Aaa</td>
<td>-2.360</td>
<td>-3.1</td>
<td>-2.625</td>
<td>-3.540</td>
<td>0.021</td>
<td>-0.584</td>
<td>-2.467</td>
</tr>
<tr>
<td></td>
<td>[2.99]</td>
<td>[4.58]</td>
<td>[2.59]</td>
<td>[4.09]</td>
<td>[0.05]</td>
<td>[1.43]</td>
<td>[2.97]</td>
</tr>
</tbody>
</table>

$\bar{R}^2$          | 0.25     | 0.3      | 0.2      | 0.36      | 0.33     | 0.28     | 0.18     | 0.16     |

Absolute t-statistics in brackets. Constants and four lags of the dependent variable included in each equation.
Table 6: Forecasting equations: Unemployment rate

<table>
<thead>
<tr>
<th></th>
<th>3 months</th>
<th></th>
<th></th>
<th></th>
<th>12 months</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Real FF</td>
<td>0.024</td>
<td>0.019</td>
<td>0.014</td>
<td>0.022</td>
<td>0.128</td>
<td>0.103</td>
<td>0.061</td>
<td>0.071</td>
</tr>
<tr>
<td>T10yr-3mon</td>
<td>−0.059</td>
<td>−0.067</td>
<td>−0.032</td>
<td>−0.033</td>
<td>−0.304</td>
<td>−0.341</td>
<td>−0.214</td>
<td>−0.229</td>
</tr>
<tr>
<td></td>
<td>[2.99]</td>
<td>[2.69]</td>
<td>[1.49]</td>
<td>[2.25]</td>
<td>[7.58]</td>
<td>[5.97]</td>
<td>[2.61]</td>
<td>[2.55]</td>
</tr>
<tr>
<td>Aaa-T10yr</td>
<td>0.056</td>
<td>0.081</td>
<td>0.073</td>
<td>0.075</td>
<td>0.173</td>
<td>0.352</td>
<td>0.129</td>
<td>0.189</td>
</tr>
<tr>
<td></td>
<td>[1.98]</td>
<td>[2.98]</td>
<td>[1.88]</td>
<td>[1.85]</td>
<td>[2.42]</td>
<td>[4.71]</td>
<td>[1.26]</td>
<td>[1.70]</td>
</tr>
<tr>
<td>Baa - Aaa</td>
<td>0.032</td>
<td>0.116</td>
<td>0.039</td>
<td>0.236</td>
<td>−0.123</td>
<td>0.144</td>
<td>0.135</td>
<td>0.470</td>
</tr>
<tr>
<td></td>
<td>[0.73]</td>
<td>[2.60]</td>
<td>[0.73]</td>
<td>[3.71]</td>
<td>[1.03]</td>
<td>[1.22]</td>
<td>[0.88]</td>
<td>[3.12]</td>
</tr>
</tbody>
</table>

\( \bar{R}^2 \)

|                  | 0.30 | 0.33 | 0.22 | 0.39 | 0.40 | 0.34 | 0.37 | 0.34 |

Absolute t-statistics in brackets. Constants and four lags of the dependent variable included in each equation.
Table 7: F-test significance levels from monthly VARs

<table>
<thead>
<tr>
<th></th>
<th>Industrial production (log)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Unemployment rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>$\pi_t - \pi_{t-1}$</td>
<td>0.045**</td>
<td>0.032**</td>
<td>0.016**</td>
<td></td>
<td></td>
<td>0.389</td>
<td>0.339</td>
<td>0.146</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi_t$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.030**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.136</td>
</tr>
<tr>
<td>$\pi_{t-1}$</td>
<td></td>
<td></td>
<td>0.003***</td>
<td>0.002***</td>
<td>0.036**</td>
<td></td>
<td></td>
<td></td>
<td>0.003***</td>
<td>0.001***</td>
<td>0.021**</td>
</tr>
<tr>
<td>$i_{10y} - i_{3m}$</td>
<td>0.170</td>
<td>0.329</td>
<td>0.390</td>
<td>0.260</td>
<td>0.243</td>
<td>0.305</td>
<td>0.485</td>
<td>0.156</td>
<td>0.182</td>
<td>0.187</td>
<td></td>
</tr>
<tr>
<td>$i_{Baa} - i_{10y}$</td>
<td>0.004***</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.002***</td>
<td>0.002***</td>
<td>0.001***</td>
<td>0.003***</td>
<td>0.002***</td>
<td>0.003***</td>
<td>0.002***</td>
<td></td>
</tr>
</tbody>
</table>

Sample period for columns 1 and 6 is 1960:1-2013:12. For others, sample ends in 2007:12.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Two day effects of Federal Reserve QE announcements (basis pts)

<table>
<thead>
<tr>
<th></th>
<th>1 year</th>
<th>5 year</th>
<th>10 year</th>
<th>Aaa</th>
<th>Baa</th>
<th>10y-3m</th>
<th>Aaa-10y</th>
<th>Baa-10y</th>
<th>Baa-Aaa</th>
</tr>
</thead>
<tbody>
<tr>
<td>QE1</td>
<td>−5†</td>
<td>−15</td>
<td>−21†</td>
<td>−15</td>
<td>−15†</td>
<td>−23*</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>QE2</td>
<td>−1**</td>
<td>10**</td>
<td>−13**</td>
<td>−3</td>
<td>−4</td>
<td>−13**</td>
<td>10**</td>
<td>9**</td>
<td>−1</td>
</tr>
<tr>
<td>MEP</td>
<td>1**</td>
<td>−6**</td>
<td>−23**</td>
<td>−21**</td>
<td>−26**</td>
<td>−22**</td>
<td>2**</td>
<td>−3**</td>
<td>−5**</td>
</tr>
<tr>
<td>QE3</td>
<td>−1</td>
<td>2**</td>
<td>8**</td>
<td>9**</td>
<td>7**</td>
<td>10**</td>
<td>−1</td>
<td>−3**</td>
<td>−2**</td>
</tr>
<tr>
<td>6/19/13</td>
<td>1**</td>
<td>24**</td>
<td>21**</td>
<td>21**</td>
<td>22**</td>
<td>21**</td>
<td>0</td>
<td>1**</td>
<td>1**</td>
</tr>
<tr>
<td>9/18/13</td>
<td>−2**</td>
<td>−13**</td>
<td>−10**</td>
<td>−5**</td>
<td>−5**</td>
<td>−10**</td>
<td>5**</td>
<td>5**</td>
<td>0</td>
</tr>
<tr>
<td>12/18/13</td>
<td>−1**</td>
<td>11**</td>
<td>9**</td>
<td>−6**</td>
<td>1**</td>
<td>10**</td>
<td>−15**</td>
<td>−8**</td>
<td>7**</td>
</tr>
</tbody>
</table>

Sample: 2008:01:07-2014:03:11, †, *, ** significant at 10, 5 and 1% levels.